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ABSTRACT

This manual is designed to help agricultural education students and teachers to apply scientific facts and principles to problem-solving procedures in determining nutritious and economical livestock feeding programs. The manual provides applied scientific activities in biological science and chemistry, mathematics, and communication skills. It contains six units that cover the following topics: livestock digestive systems; the food nutrients; nutrient requirements of livestock; types of feed and their composition; methods and procedures for determining nutrient requirements and selecting balanced diets; and feeding guidelines and example diet formulations. Units include lists of how they are related to the applied academic areas, key terms, introduction, information illustrated with line drawings and photographs, important concepts to learn, and review questions. Appendixes include a feeds composition table with energy values, nutrient requirement tables, weight-unit conversion table, and a 178-item glossary. (KC)

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# Livestock Nutrition and Feeding

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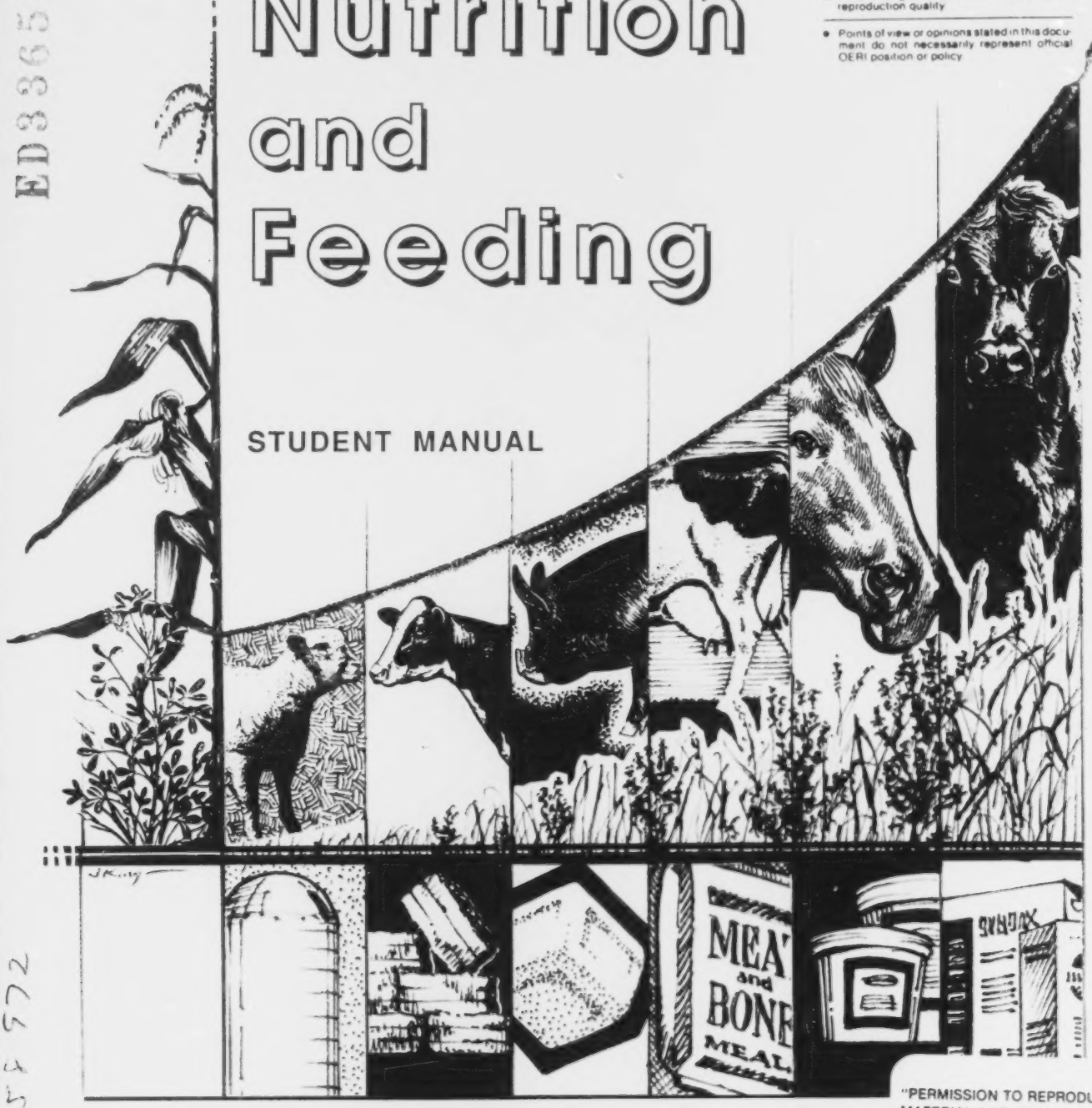
## STUDENT MANUAL

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# Livestock Nutrition and Feeding

## STUDENT MANUAL

First edition 1979
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Second edition 1991
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*Livestock Nutrition and Feeding* was originally researched and prepared for students of production agriculture by Clarence R. Fridline, an instructional materials consultant with much teaching experience. This revised edition was researched and prepared by Harlan E. Ridenour, former director of Curriculum Materials Service. Since his retirement, Dr. Ridenour, as Consultant in Educational Designing, has written animal nutrition publications for Winrock, Arkansas.

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## PREFACE

### Applied Science Areas

The study of agriculture is not a discipline that is self-contained. Rather it draws upon many disciplines that have parts related to the study of agriculture. The study of livestock nutrition and feeding draws upon and applies the biological sciences, chemistry, and mathematics. The art of communicating is also vital to the study of agriculture.

Teaching of vocational agriculture courses has traditionally been based upon problem-solving procedures and techniques. "Real-life" student problems are identified, the problem settings and solutions are explored, and the problems are clearly stated. Then all available information is brought to bear in seeking solutions to the problems. Much of this information comes from the students' present knowledge about the situation being studied. But, however extensive that may appear to be, we will be limiting ourselves severely if we depend on that information alone when solving our problems. Much scientific information has been developed by both public and private scientific investigation. This is available to farmers and agricultural educators from a variety of sources. This manual, *Livestock Nutrition and Feeding,* is designed to assist students and teachers in applying scientific facts and principles to problem-solving procedures in determining nutritious and economical livestock feeding programs.

### Biological Science and Chemistry

Biological science and chemistry are interwoven in the study of the raw materials and life processes of plants and animals.

***Anatomy*** - An understanding of the functions of the parts of the digestive system in different types of livestock is necessary in formulating appropriate diets for each livestock species.

***Plant Science*** - Students must understand how the nutritional value of different types of plants varies from one species to another. They need to see how the environmental conditions under which plants are grown can influence their nutritional value.

***Photosynthesis*** - All life on earth, both plant and animal, depends upon photosynthesis. Photosynthesis is the process by which plants use the energy of the sun in the presence of green pigmented chlorophyll to change carbon dioxide, water, and minerals (through several steps) into carbohydrates, fat, and protein. At the same time, life-sustaining oxygen is released into the atmosphere. Thus, without photosynthesis to provide us with the food we need and the oxygen we breathe, there would be no life on earth as we now know it. (See the frontispiece opposite page 1.)

***Biochemistry*** - This branch of chemistry, dealing with plants and animals, includes the biochemical processes that take place during digestion.

***Analytical Chemistry*** - Though students will not be performing analytical chemical experiments, they must have an elementary understanding of this kind of scientific activity. Analytical chemical procedures are used in determining the nutritional needs of animals and the nutritional value of the various available feedstuffs. Much of this information is presented in livestock nutrient requirement tables and in feed composition tables.

***Observation*** - Scientists are trained to observe changes taking place in the materials they are working with. These changes may be due to natural conditions such as the environment or to processes or procedures initiated by the scientist. From these observations, scientific principles are formulated. Students must be able to use these principles as they apply to the feeding of livestock.

Students must also be trained to observe how their livestock performs and reacts to different feedstuffs and to changes in the environment. Such observations assist the student in making managerial decisions while determining livestock feeding programs. An old saying among livestock feeders is, "The eye of the master feeds the cattle."

***Digestive Processes*** - The digestive processes found in the different types of livestock being fed will be studied. This involves the mechanical and chemical changes brought about in feedstuffs as they pass through the animal's alimentary canal.

*Digestion* is the physical breakdown of large particles of feedstuffs into smaller particles. The smaller feedstuff particles are then chemically converted into food nutrients that can be used by the animal.

*Absorption* is the process by which nutrients enter the blood stream to be transported throughout the animal's body.

*Diffusion* In general, substances tend to move from an area of high concentration (such as food material in the digestive tract) to an area of lower concentration (such as the bloodstream). All life processes depend on this movement called *diffusion.*

*Metabolism* is the process of using nutrients from the bloodstream to carry on body functions. Metabolism takes place in every cell of the animal's body. Metabolic rates, however, vary from one animal to another within a species and especially between species.

***Nutritional Needs of Livestock*** - Different species of livestock have different nutritional needs due to their difference in size and the structure of their digestive tract. Also, the life stage and use of an animal influences nutrient needs. Animals may be growing or mature; reproducing young and nursing young; producing meat, milk, wool, or work for humans; or maintaining their weight and condition. Each of these factors influences the nutritional needs of livestock.

***Food Nutrients*** - The various food nutrients, their sources, and their uses in the body must be identified. The amount of each nutrient required for efficient livestock production must also be identified.

### Mathematics

***Mathematical Calculations*** - Basic mathematical calculations are tools the livestock feeder must be able to use when determining economical and nutritional diets for livestock. Addition, subtraction, multiplication, division, and use of decimals, percentages, ratios, and proportions are some of the calculations necessary.

Some students lack the ability to perform basic mathematical calculations. Other students can perform the basic calculations but do not understand how to apply them to real-life situations. This unit of study enables teachers to assist students in learning to perform basic mathematical calculations and to apply these skills to meaningful, real-life situations.

***Measurements*** - The student must be proficient in reading and using units of measure when determining livestock feeding programs. Weight, volume, distance, temperature, and the density of different materials may all be involved. Students will encounter both English and metric systems of weight and measure. They must be able to use each system and convert from one to the other when necessary.

***Computers*** - Understanding the basic mathematical principles involved in livestock feeding is also a first step in mastering the use of computers in determining nutritious and economical livestock diets.

***Graphic Presentations*** - The student must learn to obtain needed information from feeding tables in determining livestock nutritional needs and the nutrient content of feedstuffs. The nutritional information presented in tables and graphs must be correctly interpreted.

### Communication

Communication is the use of language and various symbols in giving and receiving information.

***Verbal Skills*** - Students must be able to express themselves verbally when seeking or giving information. Verbal skills can be developed in students when teachers conduct classroom discussions and use conversations with individual students during supervised agricultural experience (SAE) program visits. Teachers can direct classroom and individual discussions by asking leading questions dealing with the *how, what, and why* of the issues being considered. Students should also be instructed in the skill of listening as verbal (oral) information is being presented.

***Writing*** - Students must be able to express themselves in writing - using the written word and symbols to communicate their ideas to others and to record them as a personal reference for future use.

Writing skills can be improved by requiring students to keep a notebook in which the results of classroom discussions are recorded. Additional writing skills can be developed in students as they prepare written plans of practices they intend to follow in conducting their supervised agricultural experience programs.

***Reading*** - Much of the information on livestock nutrition is presented in written form in newspaper or magazine articles, pamphlets, books, ads on television, and computer screens. When, during the decision-making process, the need for new information arises, supervised study periods can be used. Such periods can be most effective when specific questions are identified and specific reading assignments made that will provide the needed information. Reading periods should be followed by discussion periods to determine how well the students comprehended the reading material. The need to gather information will encourage students to develop their reading skills.

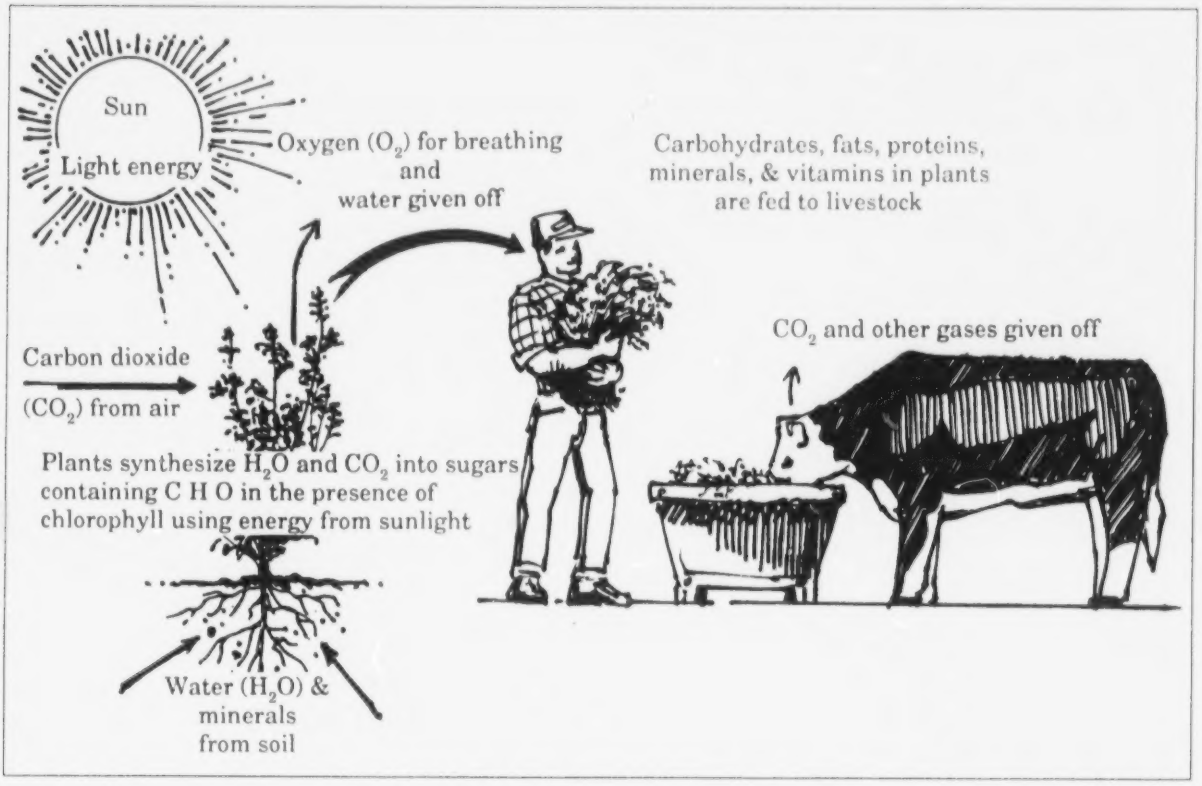
***Vocabulary*** - Students must know the meaning of many words and terms when engaged in verbal and written communication and when reading. Teachers can assist students in developing an adequate vocabulary during discussion and writing periods. A glossary of terms is included in this book to assist students in learning the meaning of terms new to them. When reading assignments are made, the meaning of new words and terms should be emphasized.

***Spelling*** - Effective communication by means of writing and reading involves a knowledge of the correct spelling of words and terms. Teachers should check students' written assignments for spelling as well as content. When reading assignments are made, terms that are difficult to spell should be identified.

***Dictionary*** - Dictionaries should be available for students to use in determining the definition and the correct spelling of words.

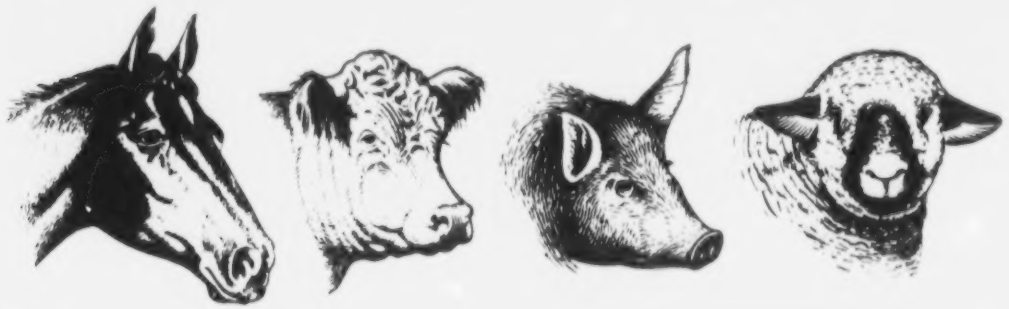
## FRONTISPIECE

Life on earth, both plant and animal, depends on photosynthesis. Energy from the sun is used by plants to synthesize plant nutrients that in turn provide nutrients for livestock when plants are eaten.


Sun
Light energy
Oxygen ($O_2$) for breathing and water given off
Carbohydrates, fats, proteins, minerals, & vitamins in plants are fed to livestock
$CO_2$ and other gases given off
Carbon dioxide ($CO_2$) from air
Plants synthesize $H_2O$ and $CO_2$ into sugars containing C H O in the presence of chlorophyll using energy from sunlight
Water ($H_2O$) & minerals from soil

UNIT 1

# LIVESTOCK DIGESTIVE SYSTEMS



## APPLIED ACADEMIC AREAS

### Biological science

- Explain digestion process
- Explain absorption process
- Explain metabolism
- Explain active transport
- Identify parts of anatomy of digestive tract
- Observe eating habits of animals

### Mathematics

- Measure volume
- Employ data analysis - read and interpret graphs, tables, charts

### Terms to know

In each unit are a number of terms that may be new to you. It is important that you know their meaning. Some of these terms are described in the text; all of them are defined in the glossary at the end of this manual.

abomasum
absorption
acid
active transport
alimentary canal
alkaline
ambient
anus
bioconverting
bloat
by-product
carnivore
cecum
colon
diffusion
digestion
duodenum
emulsify
enterotoxemia
enzyme
esophagus
feces
fistula
gastrointestinal
gluten
herbivore
lubricate
lymph
maintenance diet
metabolism
microorganisms
nonruminant
omasum
omnivore
palatability
papillae
peristalsis
putrefaction
regurgitate
reticulum
rumen
ruminant
ruminate
urea
villi
volatile fatty acid

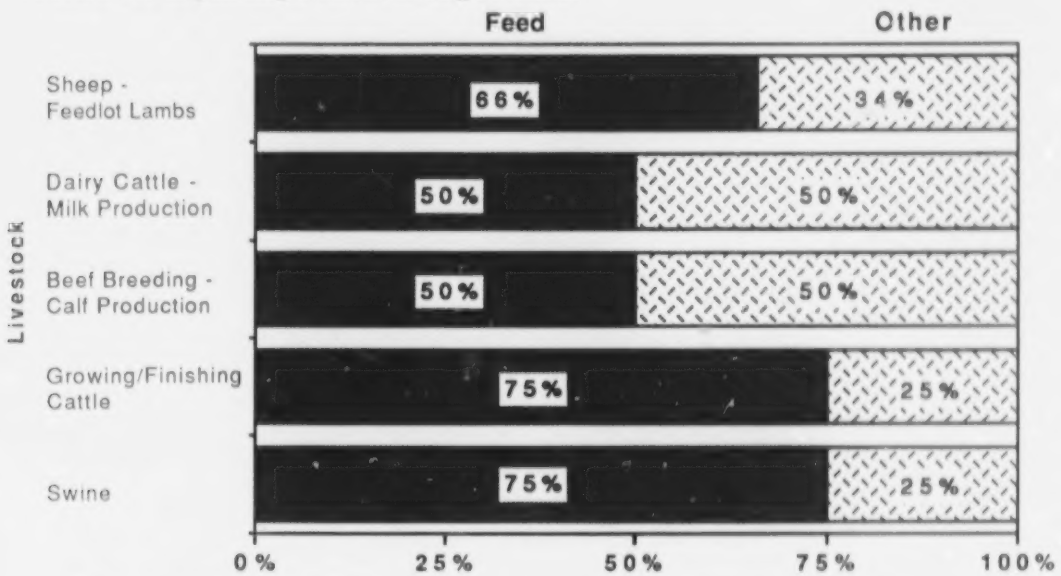
## INTRODUCTION

As we start the study of *Livestock Nutrition and Feeding*, we might ask ourselves the question, "Why do we raise livestock?" It is obvious that, depending upon the type of livestock, we are producing work animals or offspring, meat, milk, hides, wool, or by-products of the meat-processing industry that are of vital importance to people.

In addition, we want to produce a ***profit*** that will enable us to remain in business and reward us for our labor and management. There are many costs involved in raising livestock that must be recovered before we can make a profit. These costs include raising or purchasing breeding and feeder stock, management, labor, interest on capital, facilities, shelter, and feed. Of all these costs, ***feed*** makes up from 50 to 75 percent of the total cost of the operation (Figure 1).

**Figure 1**

Feed is the largest single cost in raising livestock.




Efficient and profitable livestock production depends on developing competencies in the area of livestock nutrition and feeding, since this is the most costly part of the enterprise. A working knowledge of the functioning of the digestive system of different types of livestock is vital to accomplish this.

This unit, "Livestock Digestive Systems," will provide you with certain biological principles and facts that you can use in developing feeding programs for the particular type(s) of livestock you will be raising.

## Classifying Animals

### *By Feeding Preference*

You may have already observed that different species of animals consume different kinds of food (or feed). One way of classifying all animals is in the following three groups:

**Carnivores** are *carnivorous* (flesh- or meat-eating) animals such as cats and dogs. Meat is usually readily digested and thus these animals have a relatively short and simple digestive tract. *(None of these animals are included in this manual.)*

**Herbivores** are *herbivorous* (plant-eating) animals such as cattle and sheep. Since plant materials, particularly forages, are not readily digestible, these animals have a relatively larger, longer digestive tract.

**Omnivores** are *omnivorous* ("eating-everything") animals such as swine and human beings that eat both plant and animal foodstuffs. The relative size and length of the digestive tract is between that of carnivorous and herbivorous animals.

### *By Digestive System*

The livestock that we are dealing with can easily be divided into two groups by the basic differences in their digestive systems: **ruminants** and **nonruminants**. You will learn about these two groups and what effect their differences have on feeding practices.

---

As a result of studying Unit 1, you should be able to do the following:

1. Explain the processes of digestion, absorption, and metabolism.
2. Classify farm animals as either ruminants or nonruminants.
3. Identify the parts of the ruminant and nonruminant digestive systems.
4. Explain the functions of each part of the ruminant and nonruminant digestive systems.
5. Explain why ruminant animals can consume more roughage and lower quality concentrate feeds than nonruminants can.
6. Explain the economic significance of the differences between nonruminant and ruminant livestock feed.

---

## CONVERTING FEED TO USEFUL PRODUCTION

Livestock are fed so that they can provide meat, wool, milk, or work. Three vital body processes are involved in changing feeds into useful production:

- ★ digestion
- ★ absorption
- ★ metabolism

### Digestion

Feed in the form it is fed is not directly usable by animals. By the process of digestion, however, feeds such as hay, corn, and silage can be changed into forms that are usable by animals.

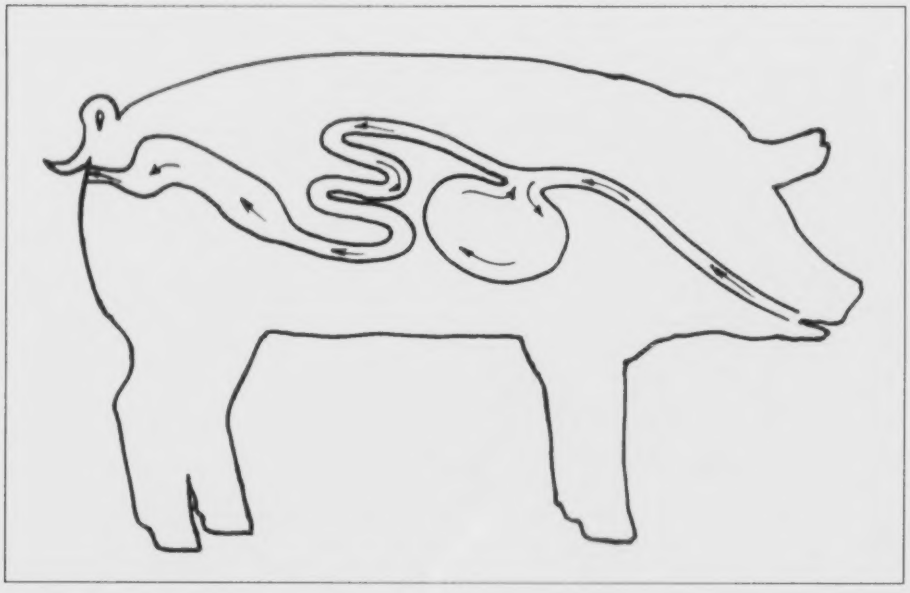
Digestion takes place in the animal's digestive system, which is sometimes called the ***gastrointestinal tract*** or the *alimentary canal.* This "canal" is like a tube that passes through the body, beginning with the lips and ending with the anus (Figure 2). The path this tube follows differs greatly from one livestock species to another, though it does the same job in all animals.

The process of digestion is both physical and chemical in nature (Figure 3). The ***physical action*** of chewing breaks down feed into smaller particles. The ***chemical action*** of acids and enzymes converts the small particles into food nutrients. The converted food nutrients are then ready for absorption and use by the animal.

---

**Figure 2**

Like a hollow tube, the digestive tract is open at both ends - from lips to anus.



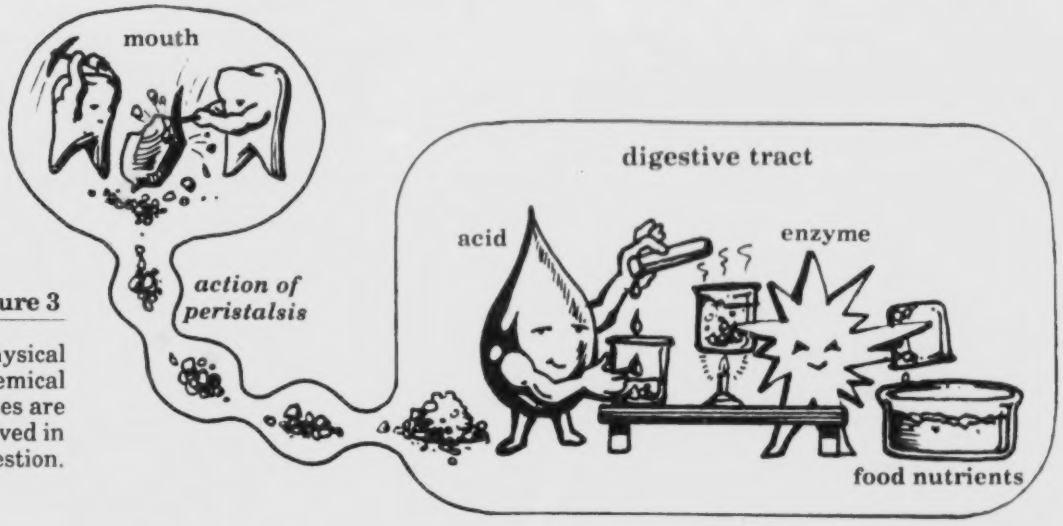



**Figure 3**

Both physical and chemical processes are involved in digestion.

An important part of the process is the mechanical action called ***peristalsis***, an involuntary rhythmic contraction and expansion of the muscles in the walls of the digestive tract. This causes the food materials to be mixed and to move through the alimentary canal. Some breakdown of food particles may also take place.

The chemical breakdown of food is due to the action of enzymes, acids, and microbes upon the foodstuffs in the digestive tract. These chemical processes will be described in more detail as the digestive process is discussed.

## Absorption

After the basic food nutrients are made available by digestion, they must enter the bloodstream for transport to all parts of the body. Absorption is the process by which nutrients move from the digestive tract, passing through its walls into the bloodstream.

Absorption takes place primarily in the small intestine through microscopic finger-like structures called ***villi***, which line the walls of the small intestine (Figure 4). Some absorption also takes place in the large intestine and the cecum of the horse. In ruminants, some types of nutrients are absorbed through the walls of the rumen.

The natural tendency is for dissolved substances like food nutrients to ***diffuse*** or move from a place where they are highly concentrated to a place of low concentration. However, when the concentration of nutrients in the bloodstream becomes higher than in the digestive tract, the nutrients do not move back into the digestive tract, but continue moving from the digestive tract into the bloodstream. This movement against the natural forces of diffusion requires energy. It is called ***active transport*** (Figure 5).

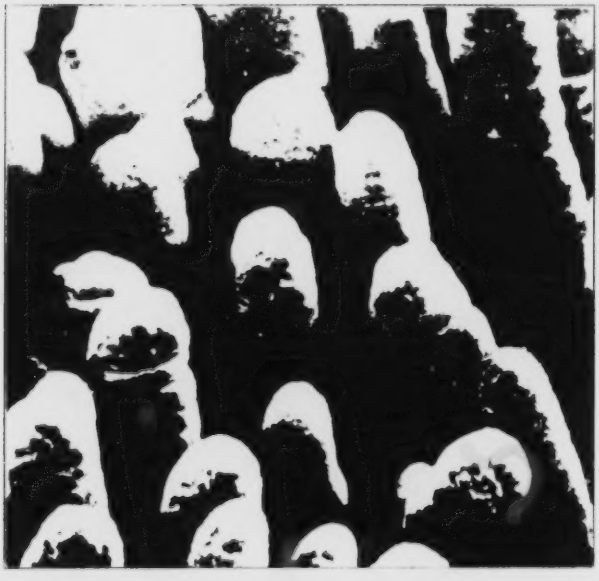


**Figure 4**

Intestinal villi of a baby pig, magnified with the aid of a scanning electron microscope. Inside the villi are small capillary blood vessels and lymph ducts which collect the absorbed material. *(USDA photograph)*



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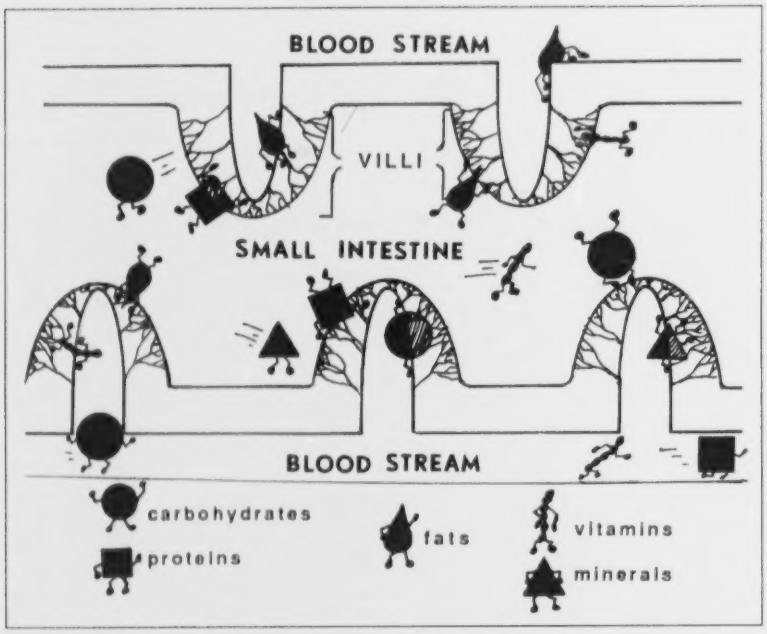



**Figure 5**

Food nutrients are absorbed into the blood stream through the villi of the small intestine.

## Metabolism

Throughout the animal body, in every cell, the transported nutrients are put to work (Figure 6). They affect the growth of bone, muscle, fat, skin, hair, and other body tissues. They help maintain body warmth and organ functioning. They repair body tissue, produce milk (lactation), produce young (gestation), affect work performance, and affect male breeding performance. Metabolism is the sum of the chemical reactions and processes by which nutrients are removed from the bloodstream and used by the animal to carry on body functions.

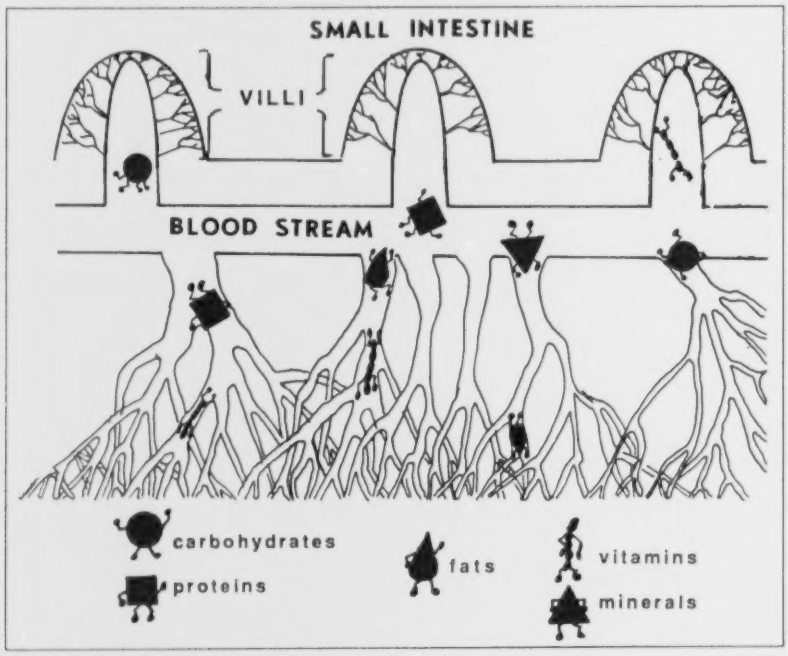



**Figure 6**

Food nutrients are transported to the various body cells by the network of blood vessels that connect them - a function of metabolism.

The processes of digestion, absorption, and metabolism enable farm animals to consume feeds in plant and animal form and convert them into food nutrients which are sources of energy, fiber, and food for humans. Foods that are unpalatable to humans are thus converted by farm animals into palatable and nutritious human food (Figure 7).

**Figure 7**

This family is eating a meal which includes meat and other livestock products. Much of what the livestock were fed would not have been suitable for human consumption. *(Roger Roediger)*

Every year the commercial food industries of the United States produce tens of millions of tons of ***by-products*** unsuitable for human consumption. For example, the corn starch and corn syrup industries produced several million tons of corn gluten feed and corn gluten meal. In addition, these industries export over one million tons of their products.

Breweries produce about half a million tons of brewers' grains, and distilleries about half a million tons of distillers' grains. The flour industry produces several million tons of wheat feed by-products. Many other by-products unsuitable for human consumption are produced. These include beet pulp, inedible molasses, fish meal, tankage, and meat scrap.

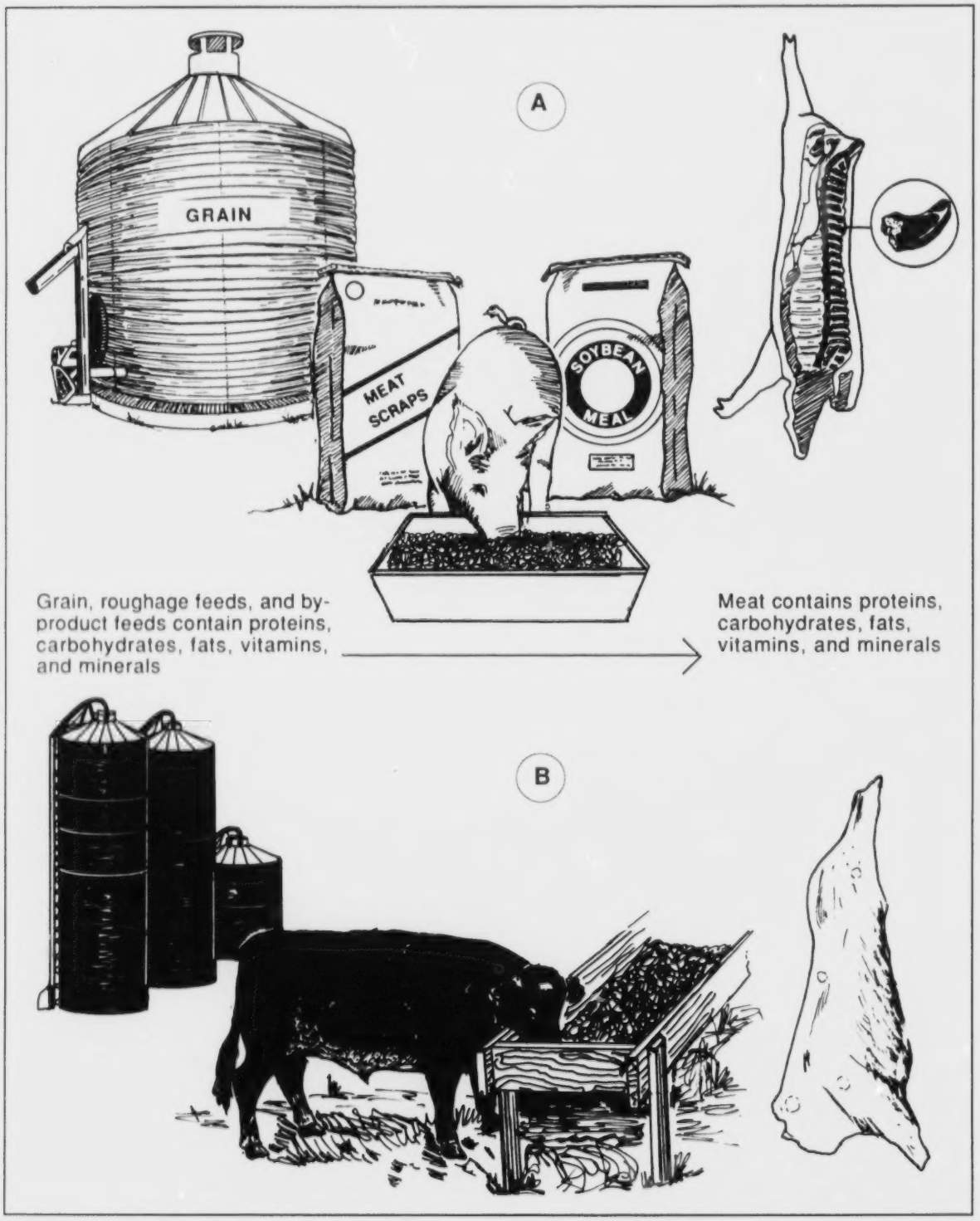
In effect, farm animals (especially ruminants) are wonderful ***bioconverting*** machines. They use the residues from human food production and the forages produced on land that can produce little else. Ruminant animals, through the microorganisms living in the rumen, convert these feeds into meat, milk, and wool. Nonruminant animals also use many of the by-products of food production (Figure 8).

## Feed Intake

The productivity of animals depends upon the amount and quality of feed consumed as well as the efficiency of both digestion and metabolism in their bodies. The amount of nutrients that have been digested and made ready for absorption and metabolism will influence total feed intake. This emphasis on greater feed intake is important in an animal's diet.

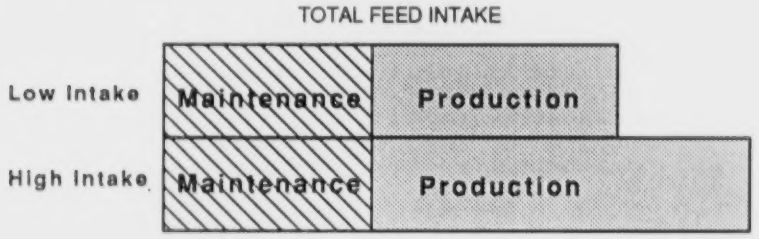
**Figure 8**

A) The pig, a nonruminant, consumes plant and animal by-product feeds, converting them into meat for human use.
B) The beef steer, a ruminant, uses roughage feeds (hay, silage, and pasture), grain, and grain by-products, converting them into food for human use.


A
GRAIN
MEAT SCRAPS
SOYBEAN MEAL
Grain, roughage feeds, and by-product feeds contain proteins, carbohydrates, fats, vitamins, and minerals
Meat contains proteins, carbohydrates, fats, vitamins, and minerals
B

First, an animal must consume enough feed to meet its ***maintenance requirements*** (the diet needed simply to keep an animal alive from day to day). The remainder of the feed it consumes, then, is used for gain or other types of production, such as milk production by dairy cows.

- Animals with low feed intake use a larger percentage of their nutrients for maintenance.
- Animals with high feed intake use a smaller percentage of their nutrients for maintenance.




So, livestock producers must increase their animals' feed intake for the most cost-effective production. A number of factors are important in getting animals to eat and gain as desired.

### *Palatability*

This is the animal's taste and preference for one feed ingredient over another. For example, adding molasses to a diet generally results in good palatability and ***increases*** feed intake. On the other hand, ***decreased*** feed intake results when palatability is poor— when the feeds offered are distasteful to the animal. For example, a beef cow offered poor-tasting wheat straw may not fill her digestive tract with it even though her body may need more nutrients. Hogs fed spoiled, poor-tasting, and bad-smelling grain may also limit their intake.

### *Appetite*

This is the amount of feed intake over a period of time. A good appetite is really the long-range goal of good palatability. For example, the molasses added to the wheat straw diet may have improved its palatability over a short period of time. But over a long period of time, it may not improve the animal's appetite or feed intake.

Some animals are simply better eaters than others. Research has shown that the trait of a good appetite or greater feed intake can be inherited.

### *Feed Quality*

High quality feeds such as grains, or immature forages such as pasture, hay, or silage can be digested and metabolized more quickly than can poor quality feeds. Thus, high quality feeds require less time to pass through the digestive tract. The longer time required for low quality feeds tends to reduce the animal's appetite.

The total intake of high quality feeds may be lower than that of poor quality feeds that cannot be digested and metabolized as quickly and efficiently. However, the total energy consumed is usually greater for high quality feeds.

### *Physical Capacity*

The physical capability of animals to hold feedstuffs also influences total feed intake. For example, when low quality feeds requiring more time for digestion are consumed, the animal may not be able to eat enough to meet its nutrient needs. An example is cattle that feed on large round bales of mature grass hay that has weathered a year or two. Also, feeds with high water content will reduce the amount of dry material the animal can consume.

It is wasteful and costly to offer an animal feed in amounts exceeding its need. Overfeeding often causes dystocia (problems in giving birth) and metabolic diseases such as ketosis. Also, overfeeding can result in an overfat carcass that is undesirable to consumers and costly to producers.

### *Form of Feed*

Certain feeds are prepared by grinding, chopping, or pelleting the material. This tends to improve the efficiency of the digestive and metabolic processes as well as to reduce the time required for these processes. One must remember, however, that while processing a feed may improve the efficiency of the digestive and metabolic processes, it will not change a low quality feed into a high quality feed.

### *Weather Factors*

Weather-related stress can play a part in feed intake. The stress of heat and high humidity tends to reduce feed intake as shown in Table 1. Prolonged extremely cold weather increases the animal's need for feed.

Table 1

Average daily intake of yearling steers as influenced by ambient temperature

| Temperature Range (Fahrenheit) | Average Daily Feed Consumed per Steer |
|---|---|
| 70-79° | 40.2 lb |
| 80-89° | 28.3 lb |
| 90° or above | 25.7 lb |

*Source: Oklahoma unpublished data*

## ANIMAL DIGESTIVE SYSTEMS - Ruminants and Nonruminants

The processes of absorption and metabolism were found to be very similar in all animals. However, not ***all*** digestive processes are alike in all animals. The anatomy and functioning of the different digestive systems directly influence the type of feeding program that must be provided. Animals commonly found on the farm have either a ***monogastric*** or a ***polygastric*** digestive system. ("Mono" means *one*; "poly" means *many*; "gastric" refers to the stomach.) Thus, monogastric animals have a single, undivided stomach. Polygastric animals have more than one compartment to their stomach.

Polygastric animals, such as cattle, ***ruminate***, or chew their cud. They are called ***ruminants***. Monogastric animals, such as swine, do not ruminate. They are the ***nonruminants***. The stomachs of ruminants and nonruminants differ in shape, size, and sometimes function. All farm animals can be classified as either ruminants or nonruminants (Figure 9).

**Ruminants** have a large-capacity stomach with more than one compartment (usually four) (Figure 10). (Note that this stomach takes up a much larger portion of the body cavity than does the single stomach of the nonruminant.) The farm animals in this group are cattle, sheep, and goats (Figure 9).

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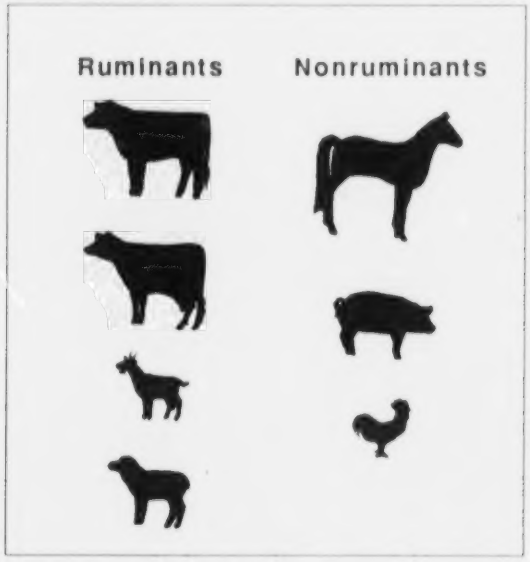
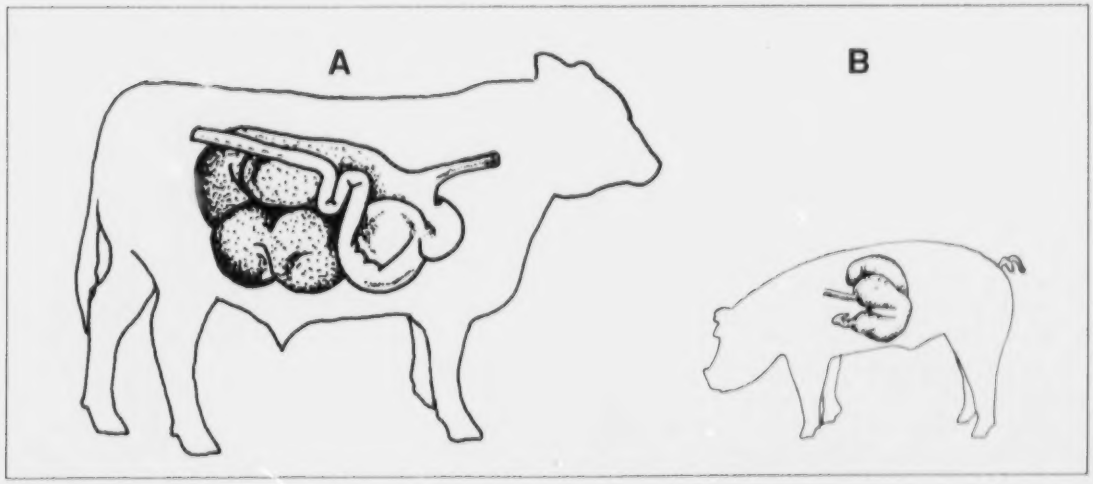



**Figure 9**

All animals on the farm can be classified as either ruminants or nonruminants

**Figure 10**

Comparison of **A)** a ruminant with four sections to the stomach; and **B)** a nonruminant with one stomach.



The stomach of ruminants, with its several compartments, enables them to consume large quantities of pasture plants such as hay and silage. Such feeds are commonly called roughages or forages. When fed high quality hay or pasture, ruminants can maintain themselves on these feeds alone (with salt and minerals added), and gain weight. For this reason, ruminants can be fed very economically when the major portion of their diet is home-grown forage. Often the forage is produced on land unsuitable for raising other crops. Even on hills, pasture can produce sufficient forage to support beef cow and calf operations (Figure 11). (The different parts of the ruminant digestive system and how they work are discussed on pages 16-19.)

**Figure 11**

Hilly pastures serve as a grazing area for beef cows and calves and for fattening steers. *(Photo courtesy of Janice Bowman)*

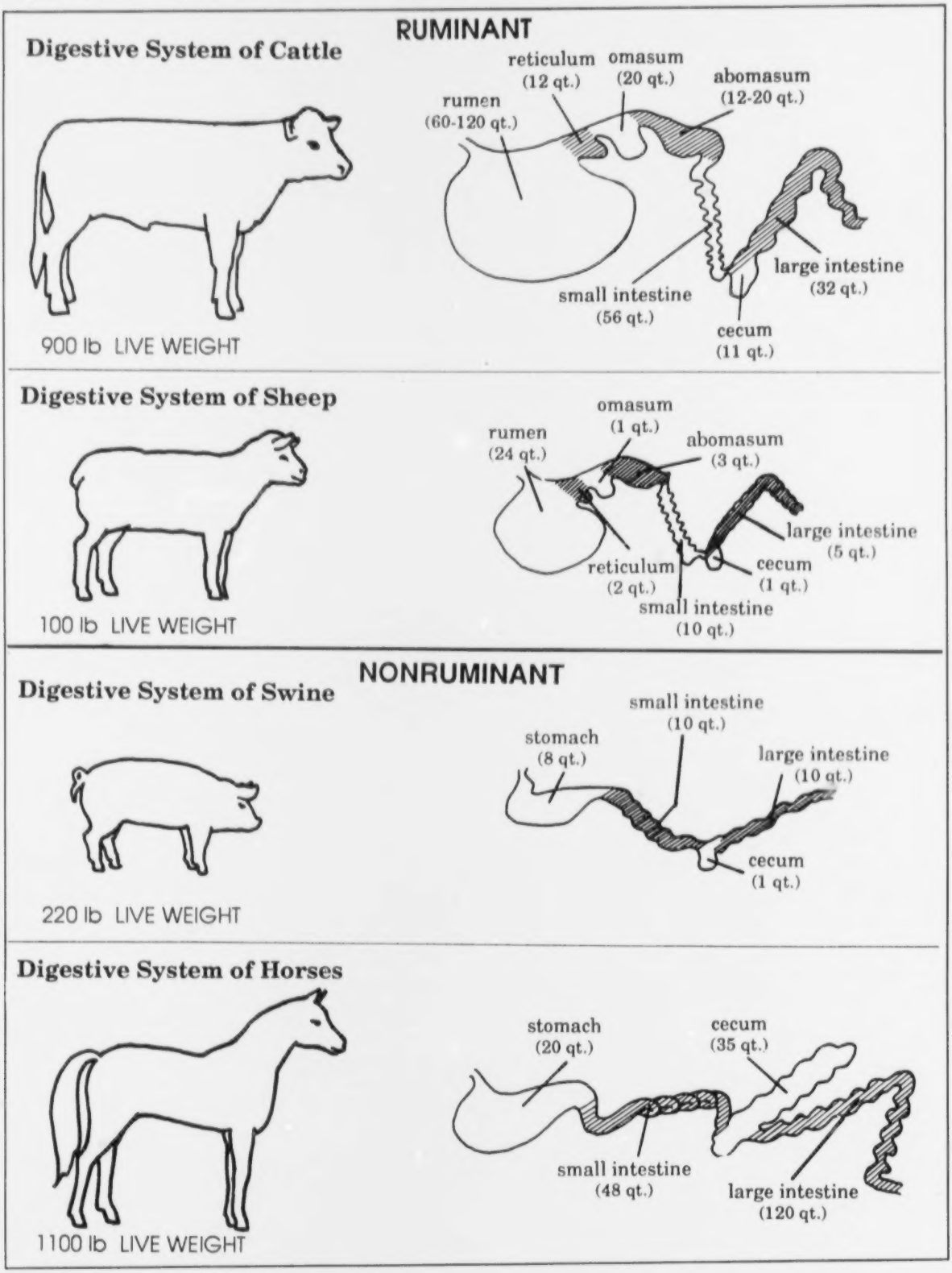
**Nonruminants** commonly raised on the farm are swine, poultry, and horses (Figures 9 and 10). The feed consumed by swine and poultry is largely concentrate feeds such as grains, grain by-products, and protein supplements. Swine and poultry consume very small amounts of roughage feed. By contrast, horses, with their large cecum, are able to digest relatively large amounts of roughage feeds, as ruminants do. (The different parts of the nonruminant digestive system and how they work are discussed in the next section, pages 14-15.)

## Digestive System Capacity

Because of the large stomach capacity of ruminants, they are able to process quantities of roughage that no nonruminant can handle. Compare the sizes of the digestive system of ruminants (cattle and sheep) and nonruminants (horses and swine) as shown in Figure 12. Note that the total stomach capacity of sheep (ruminant) is 30 quarts compared to that of swine (nonruminant) at 8 quarts. Even with larger animals, cattle (at 900 pounds) have a total stomach capacity range of 100 to 175 quarts compared to that of the horse with 20 quarts. But note, too, that the cecum of the horse is larger than that of any other animal.

**Figure 12**

Capacities of the digestive tracts of ruminants (cattle and sheep) and nonruminants (swine and horse).



## Digestive Tract of the Nonruminant

(See Figure 13)

***Mouth and Teeth*** - The mouth and teeth break feed into smaller parts by chewing.

***Saliva***, found in the mouth, is an alkaline secretion that lubricates the feed for easier passage through the esophagus into the stomach. Saliva is mixed with the food particles during chewing. It contains an enzyme which acts on carbohydrates and starts to change them from starches to sugars. This enzyme continues to act on starches after they reach the stomach. Eventually stomach acid stops the action.

***Esophagus*** - The esophagus is the passageway for food and water from the mouth to the stomach.

***Stomach*** - The digestive processes of nonruminants continue in the stomach. When food particles reach the stomach, they are mixed with acids and digestive enzymes that are secreted from the stomach lining. The mixture becomes acidic.

Feeds containing fats are partially broken down in the stomach by enzyme action. Fat digestion is completed in the small intestine.

Protein digestion begins in the stomach, where enzymes and acids are secreted. Further digestion of proteins takes place in the small intestine.

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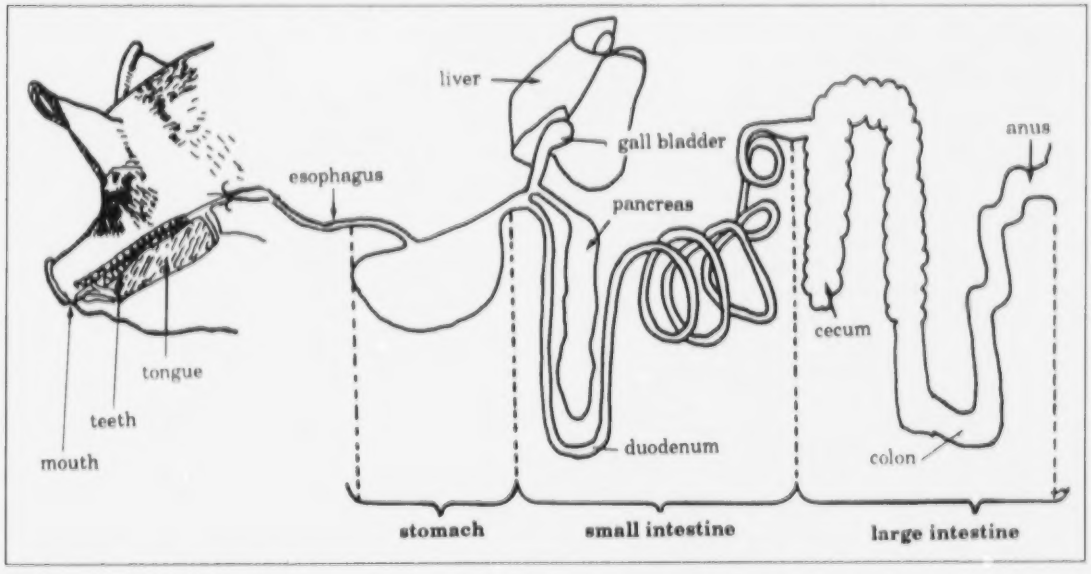
**Figure 13**

Parts of the digestive tract of a nonruminant (swine).



Carbohydrates pass through the stomach at a faster rate than the other nutrients. Most carbohydrate digestion takes place in the small intestine.

***Duodenum*** - This is the first part of the ***small intestine***. Bile from the gall bladder enters the duodenum and helps emulsify fats. Emulsification makes fats soluble in water.

Enzymes from the pancreas enter the duodenum and help break down carbohydrates and proteins. The mixture becomes neutral (around pH 7) as it is mixed with alkaline enzymes and secretions from the pancreas.

***Small Intestine*** (the remainder) - In the small intestine the digested nutrients are absorbed into the blood stream through the villi. (Refer to page 5 for a discussion of absorption.)

***Cecum*** (of the large intestine) - The cecum, often referred to as the "blind gut," serves different functions, depending on the animal species.

The cecum of swine is small when compared to the total size of the large intestine. Because of its size, though it does contain microorganisms, it plays a limited role in the digestive process of these animals.

The cecum of the horse, however, is quite large compared to that of other farm animals. In it, most of the digestion of roughage in the diet takes place. The cecum of the horse contains microorganisms which are important in the digestion of roughages. Thus, the horse can consume large amounts of hay and pasture.

***Colon*** (large intestine) - Undigested material moves into the colon.

In the large intestine, water is absorbed from the undigested material. Bacterial action takes place causing putrefaction (fecal formation). Fatty acids, produced from fermentation of fecal material, can be absorbed and used for energy. Mucus is added for lubrication. The mixture in the cecum and large intestine remains near neutral (pH 7).

***Anus*** - The anus is the passageway for feces (waste matter) from the large intestine to the outside of the body.

## Time for Feed Passage

Research on the time of passage of feed through the pig's digestive tract shows that on the average a feeding first reaches the anus within 10 to 24 hours after it was eaten. It continues to emerge until 48 to 90 hours after it was eaten. Thus, a particular feeding will pass through the anus over a period of one to three days.

Considerable mixing of feeds occurs during their passage through the digestive tract. Also, liquids and small food particles move through the tract at a faster rate than do coarse particles.

## Digestive Tract of the Ruminant

(See Figure 14)

The ruminant digestive tract is different from that of the nonruminant mainly because the ruminant has a stomach divided into several compartments (usually four). (Compare Figure 14 with Figure 13.)

***Mouth, Teeth, and Tongue*** - The functions of the mouth, teeth, and tongue of ruminants are as follows:

The ruminant has front teeth (incisors) only in the lower jaw. When cattle are grazing, their tongue wraps around grass and other forage pulling it into the mouth. The grass is cut between the lower front teeth and the upper dental pad. Sheep and goats use their lips in grazing.

The feeds taken in by ruminants are mixed with a heavy flow of saliva. Unlike nonruminants, the saliva of ruminants does not contain enzymes to aid in the digestion of starches (carbohydrates). It contains sodium bicarbonate ($Na_2CO_3$) which neutralizes the volatile fatty acids produced during roughage digestion.

When the ruminant animal regurgitates the contents of its rumen and chews its cud, the teeth further break down food materials into smaller particles. Also, more saliva is mixed with the regurgitated food.

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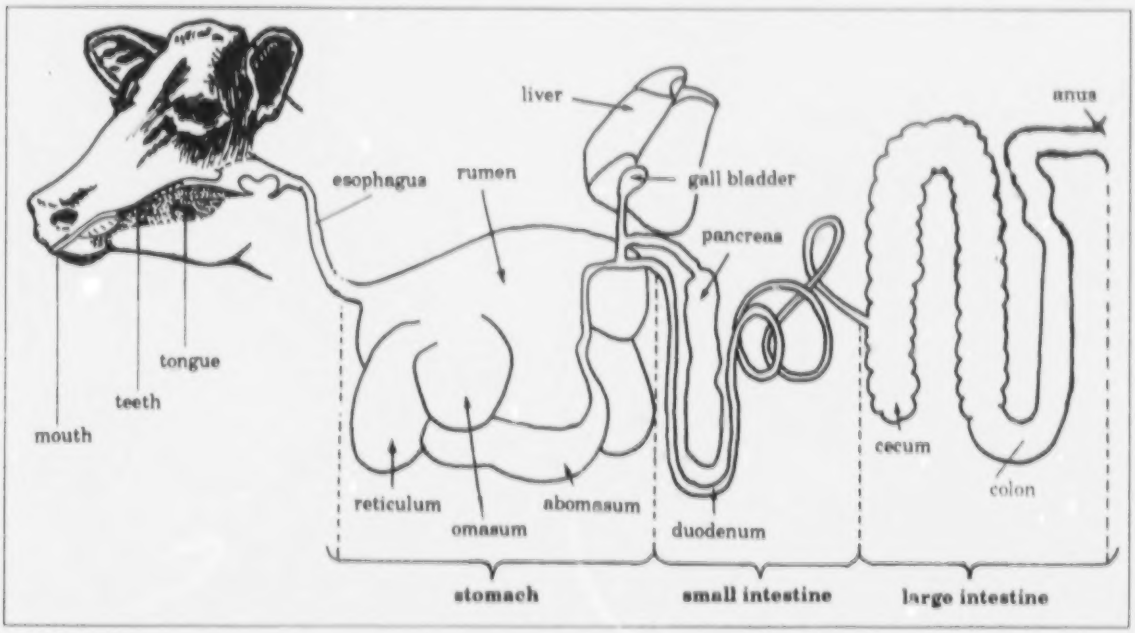
**Figure 14**

Parts of the digestive tract of a ruminant (cow).



***Stomach*** - The four compartments of the ruminant stomach are:

- ***rumen***, or "paunch,"
- ***reticulum***, or "honeycomb,"
- ***omasum***, or "manyplies," and
- ***abomasum***, or "true stomach."

***Reticulum and Rumen (Reticulo-rumen)*** *(See page 18 for a more thorough discussion of rumination.)* - About 75 percent of the digestive processing of the dry matter of feeds takes place in the rumen and the reticulum (reticulo-rumen). Ruminants rapidly gather feed, both forage and concentrates, and swallow it with little chewing. It goes directly into the reticulo-rumen, which has a greater capacity than the entire remainder of the digestive tract. Muscular action causes the feed to be continually stirred, mixed with water, and further mechanically broken down. While in the rumen, billions of bacteria and millions of protozoa and fungi assist in breaking down the feed.

Roughage such as hay and silage must be ruminated. Most grains, however, are not ruminated and therefore are not seen in the cud. It is believed that they go directly to the abomasum since they do not require rechewing or other digestive processes required for roughage. Occasionally some unground grain may be ruminated.

***Omasum*** - Less is known about the function of the omasum than other parts of the stomach because it is a difficult organ to study. Animal scientists generally believe that the main functions of the omasum are:

- to absorb water from the digesta (food particles), as they are drier when leaving the omasum than when entering; and
- to absorb volatile fatty acids.

***Abomasum*** - The abomasum or "true stomach" is similar in function to that of nonruminants.

- Digestive juices containing acids and enzymes are added and the moisture content of food particles is increased.
- Microbial and undigested feed protein from the rumen is partially digested. (The process is completed in the small intestine.)
- Very few fats or carbohydrates are digested in the abomasum.

***Duodenum*** - The function of the duodenum is the same as in the nonruminant: bile from the gall bladder enters and helps to emulsify fats. Enzymes from the pancreas enter and help break down carbohydrates and proteins. The mixture in the duodenum becomes neutral as it is mixed with alkaline secretions from the pancreas and gall bladder.

***Small Intestine*** - Just as with the nonruminant, digested nutrients are absorbed into the blood stream through the villi in the small intestine.

***Cecum and Colon*** *(Large Intestine)* - Just as with the nonruminant, undigested material moves into the cecum and colon. Here water is absorbed and bacterial action takes place causing putrefaction (fecal formation). Mucus is added for lubrication. The mixture in the cecum and colon remains near neutral. About 5 to 15 percent of digestible fiber is digested in the large intestine.

***Anus*** - For ruminants as well as nonruminants, the anus is the passageway for feces from the large intestine to the outside of the body.

## The Active Reticulo-Rumen

After a quick look through the different parts of the digestive system, we will now take a more complete look at the rumen and its importance.

**Rumination** takes place within about an hour after the reticulo-rumen is filled. The process is as follows (Figure 15):

1. The reticulum acts as a sort of pump. At the start of rumination it contracts. This forces feed in the reticulum upward and backward into the rumen where cud is formed (Figure 15A).

2. When the reticulum relaxes again, it fills up with feed that has been fermenting in the rumen (Figure 15B).

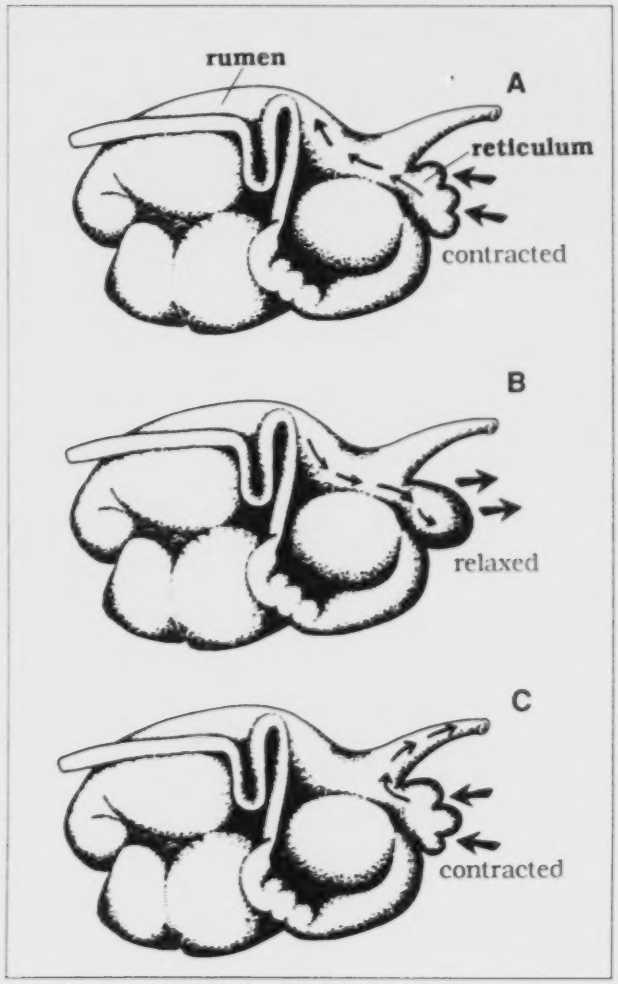
3. The reticulum contracts again to trap another supply of foodstuffs for rechewing (Figure 15C). This food is forced up the esophagus into the mouth (regurgitation). In the mouth, chewing and addition of more saliva further breaks the food down. The neutralizing effect of the saliva helps maintain the rumen in a neutral or slightly acid condition (pH 6.5–7.0). This condition is needed for efficient action of the micro-organisms in the fermentation process.

4. The material is then swallowed.

The whole process is aided by gas and muscle pressure in the rumen. The four steps complete one cycle.

**Figure 15**

In rumination the reticulum acts as a pump.




The interior wall of the rumen is lined with finger-like projections called ***papillae*** (Figure 16). They help to break down food particles. Papillae are also involved in absorption of products of microbial action and their transfer to the blood system.

The reticulo-rumen acts as a fermentation vat where microorganisms act upon high fiber roughages to break them down. For this reason, ruminants are more effective in digesting roughages (fiber) than nonruminants are (Table 2).

The reticulum is lined with honeycomb-like projections somewhat similar to the papillae of the rumen and the villi of the small intestine.

**Figure 16**

Papillae (much enlarged) in the lining of the rumen.

**Table 2**

Comparison of fiber (cellulose) digestion of alfalfa by different farm animals.

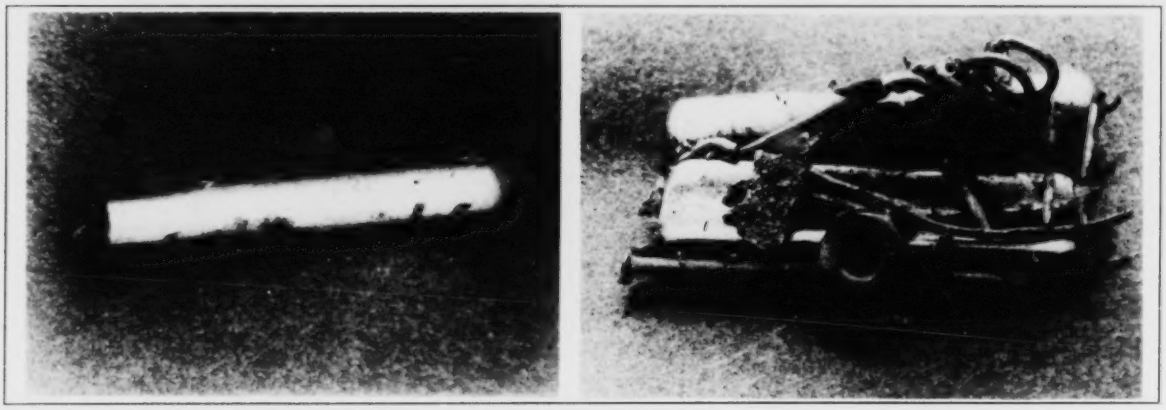
(Adapted from *Ruminant Nutrition and Physiology*, AGRA Data III, No. 4, Chas. Pfizer & Co., Terre Haute, IN)

| Kind of Livestock | Percent of Fiber Digested |
|---|---|
| Sheep | 45% |
| Cattle | 44% |
| Horses | 39% |
| Swine | 22% |

All materials eaten – digestible and indigestible – end up in the reticulum. Besides food, this is where nails, wire fragments, and other hardware sometimes lodge. A magnet can be placed in the reticulum to attract and retrieve such hardware accidentally eaten by the animal (Figure 17). "Hardware disease" is the term used when swallowed metal punctures the reticulum wall. The result can be infection of the abdomen and death of the animal.

**Figure 17**

A magnet and all the hardware that was attracted to it while in the reticulum of a dairy cow.



### Functions of Rumen Microorganisms

Numerous research studies have been made concerning the action of microorganisms in the rumen. (See Figures 18 and 19.) Three types of microorganisms are present in the rumen: bacteria, protozoa, and fungi.

***Rumen Bacteria*** - These microorganisms make the greatest contribution to digestion.

One group of rumen bacteria attacks and ferments readily available carbohydrates. These bacteria are found in greatest numbers when the diet fed consists mainly of concentrate feeds (grains and grain by-products) and young tender forages.

Other types of rumen bacteria attack and ferment the fiber part of feeds. These bacteria are found in greatest numbers when high roughage diets are fed.

***Rumen Protozoa*** - These microorganisms are not as essential in rumen digestion as bacteria are, but they are important because:

- they aid in the storage of readily available carbohydrates;
- through their action, some protein is formed; and
- they aid in fermentation of fiber.

***Rumen Fungi*** - The fungi groups are fewer in number than bacteria or protozoa. Their function is not clearly known, but they are thought to play a role in fiber breakdown.

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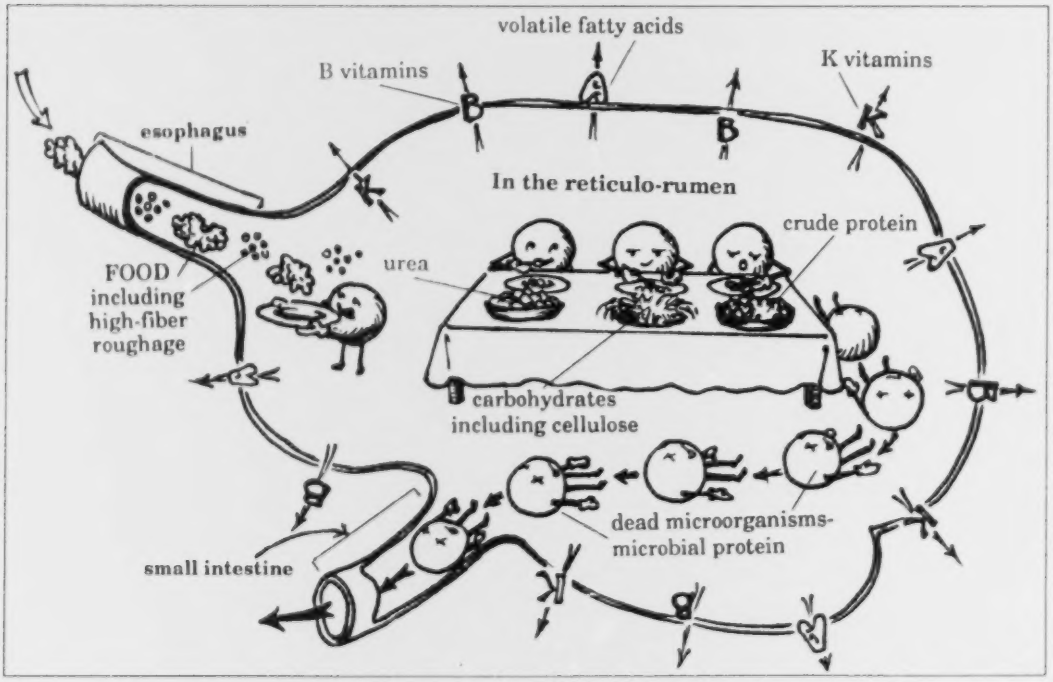
**Figure 18**

The reticulo-rumen microorganisms produce volatile fatty acids and vitamins which are absorbed directly into the bloodstream from the reticulum, rumen, and omasum. When the microorganisms die, they pass from the stomach into the small intestine.

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From this discussion it can be seen that the type of microorganism in the rumen depends, to a great extent, upon the kinds of feed being fed to the ruminant - roughages or concentrates. A sudden change in feed will often cause a ruminant to go "off feed." This will continue until the microorganism population becomes adjusted to the new feed material. Thus, changes in an animal's diet should be made ***gradually***.

The fermentation process in the reticulo-rumen produces large amounts of carbon dioxide and methane gases. While ruminants are able to release these gases by belching, they are not able to get rid of other rumen contents by vomiting. This inability to vomit protects valuable rumen microorganisms, but makes ruminants more susceptible to poisoning, bloat, and other diseases.

### Nutrient Digestion in the Rumen

The microorganisms of the rumen are the active digestive units in nutrient formation and use.

***Carbohydrates*** of any kind - starches, sugars, or cellulose - are changed into ***volatile fatty acids***. The three most important fatty acids are acetic acid, propionic acid, and butyric acid.

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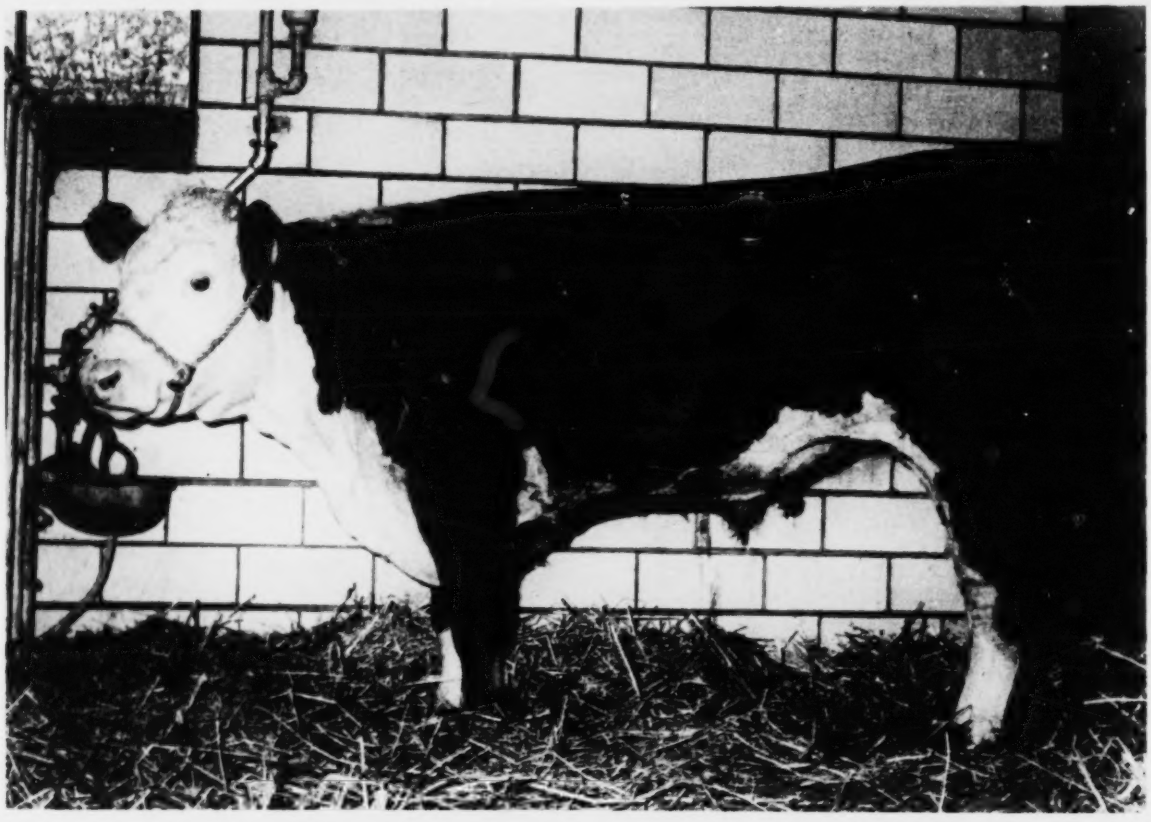
**Figure 19**

A fistula has been placed in this steer, opening into the rumen. Animal scientists are able to remove contents of the rumen for laboratory analysis. *(Ohio Agricultural Research and Development Center)*





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About 60 to 70 percent of the carbohydrate part of the feed diet is digested in the rumen. Most of this is converted into these acids and absorbed directly into the bloodstream from the rumen. The papillae, which line the rumen walls, function similarly to the villi of the small intestine and aid in absorption.

***Protein synthesis*** (manufacture or building) occurs in the rumen. The rumen microorganisms break down either protein or ***urea*** (a nonprotein nitrogen source) and, from the residues, produce microbial protein.

Microbial protein is digested in the abomasum and small intestine of the ruminant, producing amino acids. Thus, ruminants do not have to be supplied with all the amino acids, as nonruminants do. However, they grow faster and produce more milk if fed protein than they do if fed urea.

***Vitamins*** - Filling the vitamin needs for mature ruminants is made easier because their bodies synthesize both B-complex vitamins and vitamin K. No additions of these vitamins have to be made in the diet. They move (are assimilated) into the bloodstream through the papillae of the rumen or the villi in the small intestine. (After microbes are digested, they release their synthesized vitamins.)

## Early Development of the Ruminant Stomach

Very young ruminants must be fed like nonruminants because their rumen has not yet developed. At birth and in the early weeks, the abomasum ("true stomach") is the largest and the only functioning compartment of the stomach (Figure 20). Milk and other liquid materials pass from the esophagus to the abomasum through the esophageal groove.

Under normal conditions, the rumen develops as follows:

- At birth, the abomasum and omasum make up 50 to 60 percent of the capacity of the stomach; the rumen and reticulum about 30 to 50 percent.

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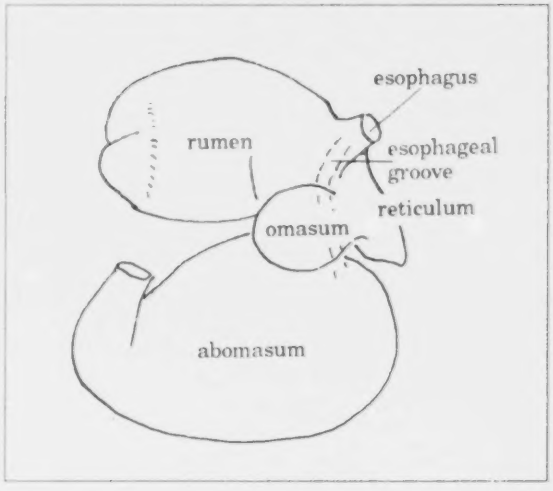
**Figure 20**

Calf's stomach at birth. Note size of abomasum compared to the other three compartments.



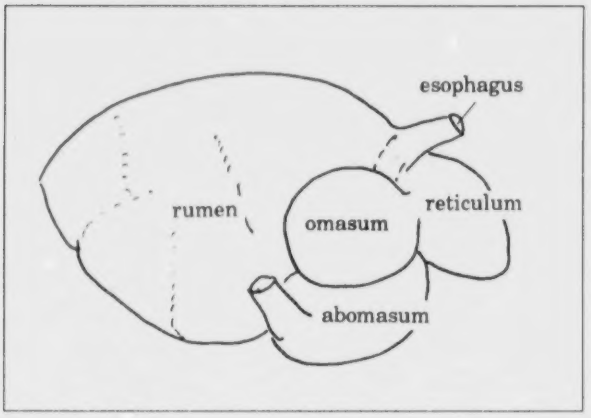



**Figure 21**

Calf's stomach at two months. Rumen is 80% of its mature size.

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✣ At about two months of age, the rumen descends from the upper left location to its normal position in a mature animal. At this age, the rumen is about 80 percent of its eventual mature size (Figure 21). The reticulum and omasum have also grown and developed.

Research conducted by the Dairy Science Department of the Ohio Agricultural Research and Development Center (OARDC) has shown that young calves can be offered high quality roughage as early as three days after birth. When calves were fed some roughage at an earlier age than usual, it was found that the rumen of these calves developed faster. However, for two or three weeks after birth, young calves and lambs do require milk or milk proteins.

## Time for Feed Passage

When ruminants are fed a normal diet, the following are the approximate times required for feed to pass through the digestive tract:

| | |
|---|---|
| rumen and reticulum (reticulo-rumen) | 61 hours |
| omasum | 8 hours |
| abomasum | 3 hours |
| small intestine | 7 hours |
| large intestine | 8 hours |

High-quality feeds are broken down and digested at a faster rate than low-quality feeds. Thus, high-quality feeds will require less time to pass through the digestive tract than low-quality feeds. Liquids and small food particles also move through the digestive tract at a faster rate than coarse particles. The average time required for feeds to pass through the digestive tract is about four days. Food can take three possible routes as it passes through the stomach compartments, as shown in Figure 22.

⇨

**Figure 22**

Three possible routes of feed in ruminants

1. **The route of ground concentrate or cud** - the most direct route of digestion

   - ***Ground concentrate*** includes corn, wheat, oats, soybean meal, tankage, and synthetic urea.

   - ***Cud*** is a ball of feed that is regurgitated and rechewed. After rechewing, it follows this most direct route:

     mouth → esophagus → reticulum → omasum → abomasum → small intestine → large intestine → anus (as waste)

2. **The route of light grain**

   - ***Light grain*** includes oats, barley, rye, etc.

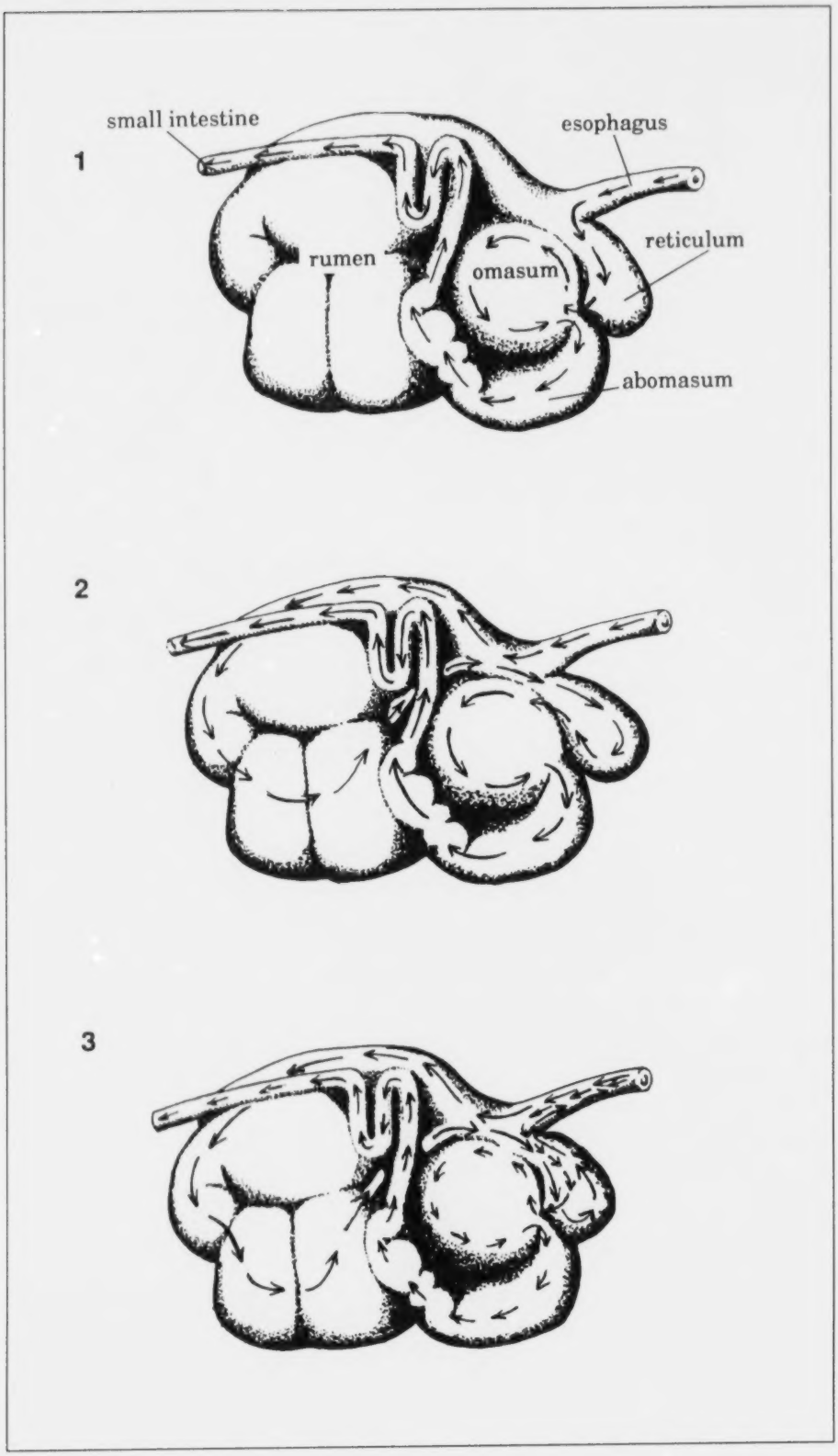
     Pushed into back of rumen, it travels around in rumen → reticulum (without regurgitation) → omasum → abomasum → small intestine → large intestine → anus (as waste)

3. **The route of forages**

   - ***Forages*** include hay, grass, corn fodder, corn, and grass silage.

     Route: all around the rumen → reticulum, then regurgitated → mouth (as cud; then swallowed) → (back to) reticulum → omasum → abomasum → small intestine → large intestine → anus (as waste)

**Figure 22**


small intestine
esophagus
1
rumen
omasum
reticulum
abomasum
2
3

**Important biological concepts to learn from Unit 1:**

- ★ Both plant and animal forms of life depend upon the process of photosynthesis.
- ★ Farm animals are bioconverting machines using residues from food product manufacturing, forages, and grains to produce high quality food nutrients, wool, hair, hides, and work for human use.
- ★ Much of the feed consumed by livestock is unsuitable for human consumption; thus, livestock are not highly competitive with humans for food. Forages in particular can be raised on land unsuitable for human food production.
- ★ The unique characteristics of the stomachs of ruminants and of nonruminants have a great influence on the kind and quality of feed each type of animal can consume and digest. ***Ruminants*** have a large stomach with many compartments containing microorganisms. This stomach acts as a fermentation vat to break down roughages into nutrients usable by the animal. ***Nonruminants*** have a smaller single-compartment stomach and can use only small amounts of roughage. They depend more on concentrated feeds.

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## REVIEW of Unit 1

After studying this unit, "Livestock Digestive Systems," you should be able to answer and discuss the following questions.

1. Why do people produce livestock on farms? *(page 2)*
2. List the major costs of producing livestock. Which of these costs makes up the greatest part of the total cost? *(page 2)*
3. One classification or grouping of all animals is according to the types of feed consumed. What are the three groups mentioned and what kind of feed does each consume? *(page 3)*
4. Why is it important for livestock feeders to have a knowledge of livestock digestive tracts and how they function ? *(page 3)*
5. As you observed the feeding of cattle, sheep, swine, and horses, what kinds and proportions of the following feeds did each consume?
   - grain
   - purchased supplements
   - roughages including pasture, hay, silage and fodder
6. Describe the process of digestion. *(pages 3-5)*
7. Describe the process of absorption. *(page 5)*
8. Describe the process of metabolism. *(page 6)*
9. What is peristalsis? What is its function during the digestive process in ruminants and in nonruminants? *(page 5)*
10. What is "active transport"? What is required to make it work? *(page 5)*
11. What does the term "bioconverting" mean? How is it important in the production of food for humans? *(page 7)*
12. What are some of the factors that determine the amount of a certain feed an animal will consume? *(pages 7, 9-10)*
13. What are the two main groups of animals when separated according to the type of digestive system? Describe the differences between the two systems. *(pages 10-12)*
14. Explain the functions of microorganisms in the digestive tract of ruminants. How do these microorganisms affect the kinds of feed provided? *(pages 20-21)*
15. Prepare a chart as illustrated below, giving the parts of the ***nonruminant*** digestive tract. Briefly describe the functions of each part, including all items (like enzymes) that are needed for the part to function. *(pages 14-15)*

**Nonruminant Digestive System**

| Digestive System Part (Component) | Function | What is Needed for Part to Function |
|---|---|---|
| *Example:* Mouth and teeth | Break food down into smaller particles; mix food particles with saliva | **Saliva** contains enzymes; changes starches to sugars; lubricates food for easier swallowing and passage through esophagus to stomach |

*Unit 1 Review - page 2*

16. Prepare a chart as illustrated below, giving the parts of the ***ruminant*** digestive tract. Briefly describe the functions of each part, including all items (like enzymes) that are needed for the part to function. *(pages 16-18)*

**Ruminant Digestive System**

| Digestive System Part (Component) | Function | What is Needed for Part to Function |
|---|---|---|
| *Example:* Mouth, teeth, and tongue | Lower incisors (front teeth) only. Tongue a clasping lever enabling lower teeth to cut off pasture plants. Saliva mixes with food as teeth break it into smaller particles. Regurgitation process - food broken into much smaller particles and mixed with more saliva. | **Saliva** contains sodium bicarbonate which neutralizes fatty acids. Starches not changed to sugar in mouth. Neutralizing effect of saliva required for efficient action of rumen microorganisms. |

17. Explain why life on earth, both plant and animal, depends on the process of photosynthesis. *(Preface)*

## UNIT 2

# THE FOOD NUTRIENTS

### APPLIED ACADEMIC AREAS

**Biological science**

- Analyze food nutrient content of animal feedstuffs and link to animal's health and production
- Explain functions of food nutrients
- Employ analytical chemistry - use bomb calorimeter to determine gross energy
- Determine energy content of feedstuffs
- Explain heat increment
- Explain oxidation
- Explain synthesis
- Explain respiration
- Explain solubility

**Mathematics**

- Measure energy values - use calorie system
- Determine percentages
- Measure weights: metric and avoir-dupois (macro/micro units)
- Determine proportions of a nutrient in a given feedstuff
- Employ data analysis - read and interpret graphs, tables, charts

**Terms to know**

air dry
amino acid
anemia
as-fed
ash
body composition
bomb calorimeter
calorie
carbohydrate
catalyst
cell membrane
cellulose
coagulation
commodities
compound
conformation
consumption
deficiency
dehydration
dry matter
element
energy
epithelium
feedstuff
fermentation
formulate
free choice
genetic
glucose
glycogen
hemoglobin
hemorrhage
hormone
lipid
macro-element
metric system
micro-element
noxious
nutrient
osmosis
osteomalacia
oxidation
precursor
productivity
protein
resin
respiration
rickets
scours
soluble
synthesis
thrifty
thyroxine
trace mineral
unthrifty
wax

## INTRODUCTION

Unit 2 identifies the food nutrients contained in feedstuffs that are essential for the health and productivity of livestock. This unit also identifies the functions performed by each of the nutrients in the animal's body and the forms in which these nutrients are measured. This information will be useful in identifying the nutrient requirements of livestock and in formulating their diets.

---

As a result of studying Unit 2, you should be able to do the following:

1. Define "food nutrient."
2. List the food nutrients.
3. Explain the functions of each food nutrient as used by farm animals.
4. Describe the effect of feed quality on the feeding of ruminants and nonruminants.
5. Recognize the differences between crude (total) and digestible protein and determine which form should be used in formulating specific diets.
6. Describe the differences between gross energy (GE), digestible energy (DE), metabolizable energy (ME), and net energy (NE).
7. Determine which form of energy should be used in figuring energy requirements for specific livestock.
8. Describe the calorie system of measuring energy.

---

## THE GROUPS OF FOOD NUTRIENTS

Farm animals require six basic food nutrients. These nutrients are used by animals for body maintenance, growth, performance of work, and production of meat, milk, eggs, and fiber. To a large extent, the health and productivity of farm animals is dependent upon receiving the correct amount of each of the following six basic nutrients:

- ★ carbohydrates
- ★ lipids (or fats)
- ★ proteins
- ★ water
- ★ minerals
- ★ vitamins

Each of the food nutrients performs specific functions in the animal's body. However, none of the nutrients acts alone. There is much interaction between nutrients in the metabolic process to keep the body functioning normally.

***Air***- Though air is not really a nutrient, it is required as a source of oxygen. The oxidizing (burning) of carbon and hydrogen contained in food nutrients provides energy for the animal.

## Carbohydrates

All carbohydrates are made up of carbon (C), hydrogen (H), and oxygen (O). These three elements can be combined in many different ways. The result is the formation of many different kinds of carbohydrates. The three major kinds of carbohydrates are sugars, starches, and fiber.

### *Energy*

The elements that make up carbohydrates (C, H, and O) are the same as those in our common fuels– coal, oil, and gas. Energy is made available for the animal to use through the burning of carbohydrates within its own body. These internal metabolic processes release energy, carbon dioxide, and water in a manner similar to the burning of coal or gas.

Energy provides the power required for muscle movement which enables the animal to walk, run, and work (Figure 23). Muscle action requiring energy is also necessary for such body functions as breathing, beating of the heart, chewing, peristalsis, digestion, absorption, and metabolism.

Carbohydrates are converted into:

- body fat
- milk fat and lactose
- blood sugar
- muscle and liver glycogen
- carbon units for synthesis of protein
- structural units of the animal's body

**Figure 23**

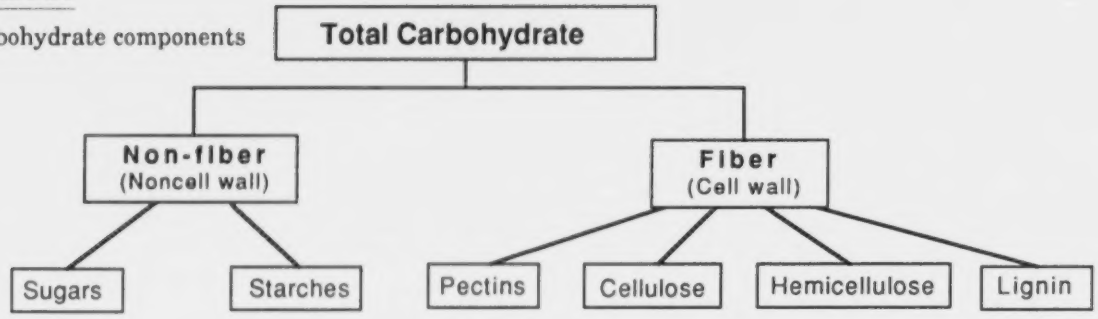
Race horses must be fed a high diet of carbohydrates to meet the energy requirements of hard work.
*(Photo courtesy of Janice Bowman)*

### *Forms of Carbohydrates*

Carbohydrates make up about 75 percent of all the dry matter in hay and 80 percent or more in grain. In the usual analysis of feeds, carbohydrates are divided into two groups: ***non-fiber*** (noncell wall) carbohydrates and ***fiber*** (cell wall) carbohydrates. The non-fiber group, which is composed of starches and sugars, is rapidly digested. The fiber carbohydrates tend to be digested slowly; they include pectins, cellulose, hemicellulose, and lignin (Figure 24).

**Figure 24**

Carbohydrate components




### *Fiber*

Fiber is the woody part of plants. With the exception of the horse, nonruminant farm animals cannot use large quantities of fiber-containing feeds in their diets. By contrast, ruminants can make good use of fiber. All animals need enough fiber in their diets to provide bulk for proper functioning of the digestive system. In ruminants the rumen microorganisms break down the fiber into nutrients (volatile fatty acids) which are absorbed into the bloodstream directly from the rumen. A similar process occurs in the digestion of fiber in the cecum of the horse.

The ***total fiber*** content of a feedstuff can be determined by laboratory analysis. Feedstuffs are soaked in a neutral detergent solution to remove all nutrients except fiber. The fiber residue is called ***neutral detergent fiber (NDF)*** and is measured in percentage of the feed. NDF is the method now used in place of nitrogen-free extract to measure the fiber in a fiber carbohydrate. Animal nutrition specialists have determined the NDF of many feedstuffs.

Feeds low in NDF are fed to farm animals whenever a rapid gain in weight is desired. These feeds are not as bulky and they supply a high proportion of easily digested carbohydrates. For example, cereal grains such as corn have a low NDF content (14 percent of the total carbohydrate content; the remainder is starch.) In contrast, ruminant animals can be fed roughage feeds with fairly high fiber contents. For example, roughages such as alfalfa hay have a fairly high NDF content (40 percent of the total carbohydrate content). Table 3 shows the percentage of non-fiber carbohydrates (NFC) and neutral detergent fiber (NDF) content of several livestock feeds.

## Fats or Lipids

"Fats" is the term commonly used to refer to all lipids even though lipids do contain other fat-like substances in addition to fats. These substances include oils, waxes, resins, organic acids, plant pigments, and vitamins A, D, E, and K. The basic difference between fats and oils is that at room temperature fats are solid and oils are liquid.

Like carbohydrates, fats contain carbon (C), hydrogen (H), and oxygen (O). However, they contain more carbon and hydrogen and less oxygen than carbohydrates do. As a result, fats produce 2.25 times as much energy as carbohydrates or proteins do (Figure 25).

High quantities of fats are not usually added to a diet unless a very high-energy diet is needed. Livestock nutritionists believe that most animals require certain minimum quantities of fats in their diet. But they have shown that most livestock diets contain sufficient fatty substances. Determining the fat content of a diet, therefore, is less critical than determining other nutrients.

**Table 3**

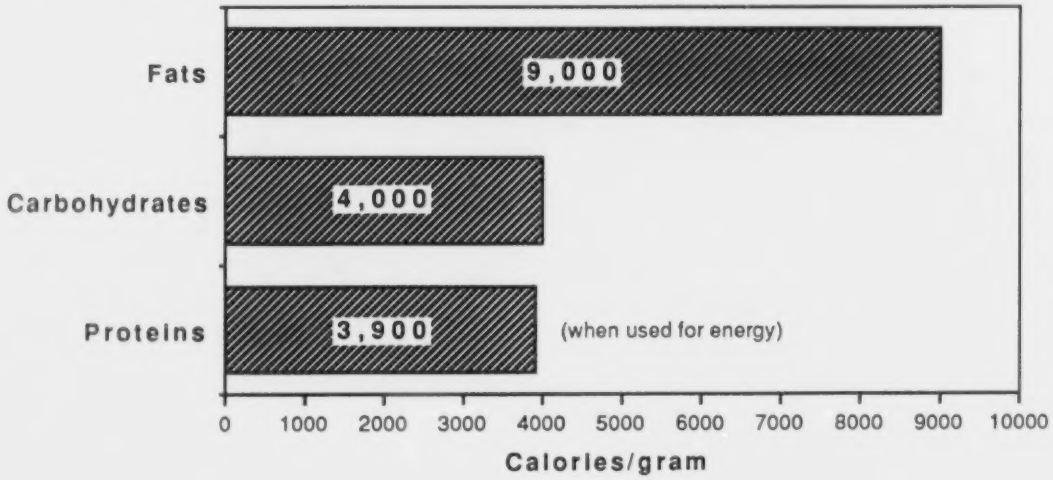
Carbohydrate fractions of selected feedstuffs

| Feedstuff | Total Carbohydrate (% DM) | NDF[1] (% DM) | NFC[2] (% DM) |
|---|---|---|---|
| *Forages* | | | |
| Alfalfa hay, late vegetative | 65 | 40 | 25 |
| Grass hay, late vegetative | 67 | 57 | 10 |
| Corn silage, well eared | 85 | 45 | 40 |
| Corn silage, few ears | 84 | 55 | 29 |
| *Concentrates* | | | |
| Barley | 84 | 28 | 56 |
| Beet pulp | 84 | 54 | 30 |
| Brewers grains | 59 | 46 | 13 |
| Corn cobs | 95 | 90 | 5 |
| Corn gluten feed | 68 | 41 | 27 |
| Corn grain | 88 | 14 | 74 |
| Cottonseed meal | 47 | 34 | 13 |
| Oats grain | 79 | 32 | 47 |
| Soybean meal (44% crude protein) | 41 | 14 | 27 |
| Soyhulls | 84 | 70 | 14 |
| Wheat grain | 85 | 14 | 71 |
| Wheat middlings | 73 | 37 | 36 |

[1] NDF=neutral detergent fiber
[2] NFC=nonfiber carbohydrate

**Figure 25**

Comparison of the number of calories in one gram of fats, carbohydrates, and proteins



### *Functions of Fats*

Because fats play a role in many essential body functions, they must be present in the animal's diet. Among other things, fats:

- provide energy for the animal (2.25 times as much as carbohydrates or proteins do)
- are a part of the cell membrane
- are a part of the nerve tissue and brain
- act as emulsifying agents
- contain fat-soluble vitamins A, D, E, and K
- provide essential materials for the secretion of hormones

## Proteins

While carbohydrates and fats are the main sources of energy, proteins supply the building materials from which body tissue and many body regulators are made (Figure 26). The word ***protein*** comes from Greek, meaning "of primary importance."

Proteins are complex compounds composed of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sometimes small quantities of other elements.

### *Functions of Proteins*

Proteins:

- are used in the body to build, repair, and maintain body tissues, muscles, skin, hair, and hooves
- are required for the production of body regulators such as enzymes and some hormones

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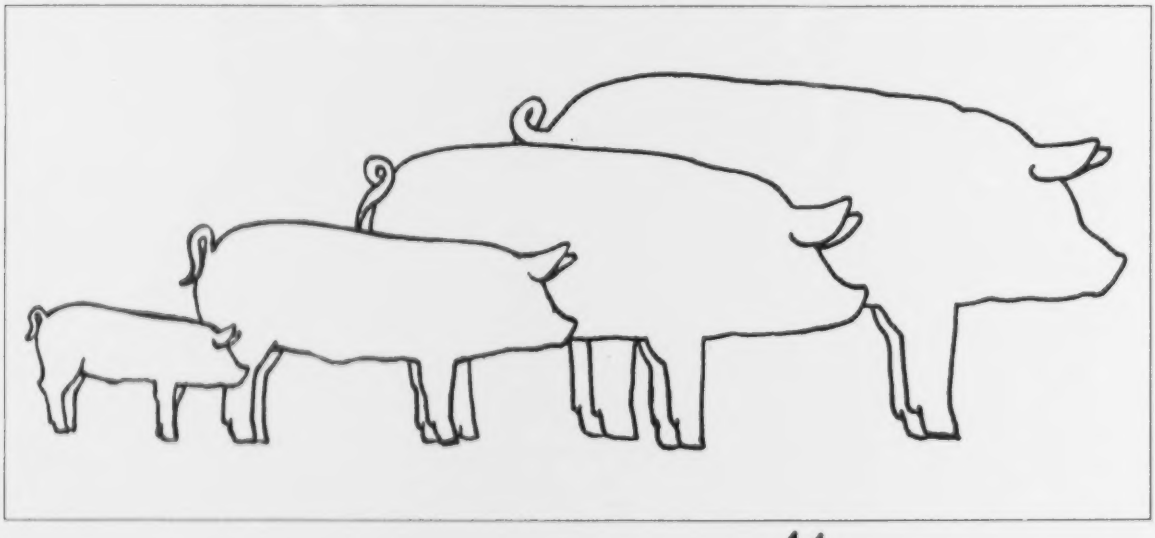
**Figure 26**

Proteins are used for growth, repair of body tissue, and production of enzymes and hormones.



- can be a source of blood glucose
- serve as a precursor of some B-complex vitamins
- are modified into certain genetic compounds in DNA, RNA, and ATP
- provide energy when fed in excess of the body's need for protein

Animals that do not receive enough protein become thin and gaunt and develop a rough hair coat. They also have poor appetites, lower digestive efficiency, and lower production. Death may occur if corrections are not made in the diet.

Sometimes nonruminants show symptoms of protein starvation even when the correct amount of protein is being fed. This could be due to problems with the amount and availability of amino acids in their diet.

## *Amino Acids*

Each protein is made up of several nitrogen compounds called ***amino acids.*** They are the bricks and mortar of which bodies are built (Figure 27). No two proteins are alike, even when made of the same amino acids.

There are at least 23 amino acids, which can be grouped into ***essential*** and ***nonessential*** amino acids (Table 4). Both groups are required by animals for normal growth and development. But the ten essential amino acids are not made in large enough quantities in the nonruminant's body to meet its nutritional requirements. Animals such as swine cannot synthesize these ten essential amino acids. Therefore, they must be supplied in the diet. Figures 28 and 29 show the effects of lysine deficiency and isoleucine deficiency in swine diets.

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**Figure 27**

Amino acids - the "building blocks" of protein.

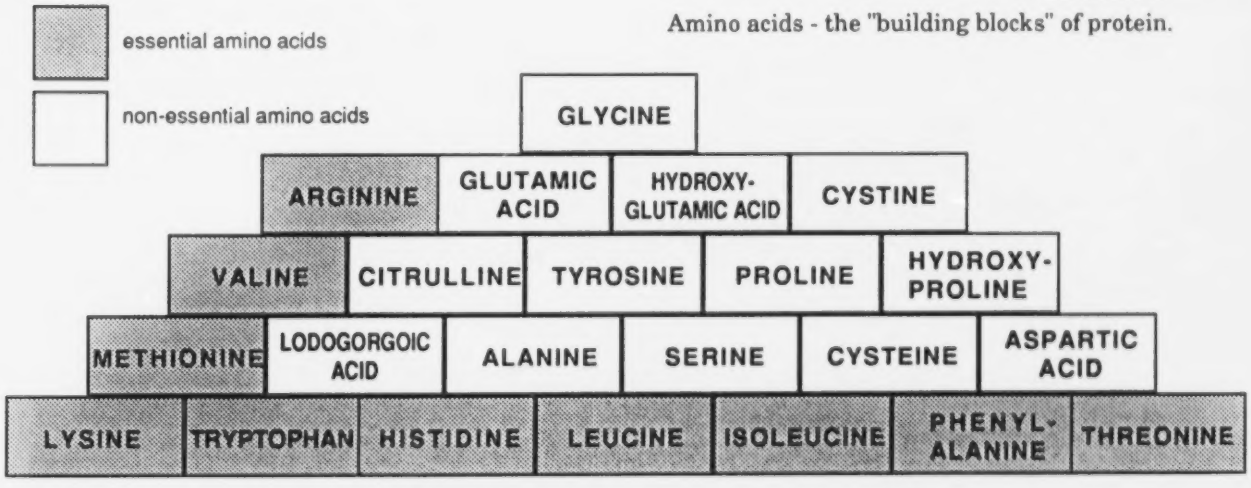


**Figure 28**

Pig A on the left was fed a lysine-deficient diet for 84 days; pig B was fed a diet with enough lysine. Note the difference. *(University of Illinois Circular 866)*

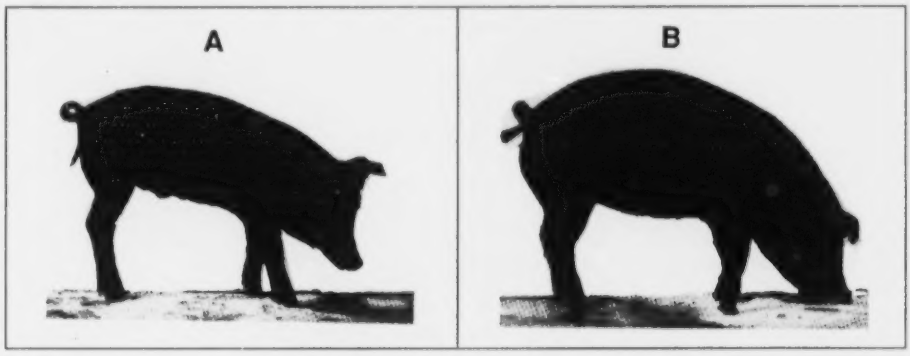



**Table 4**

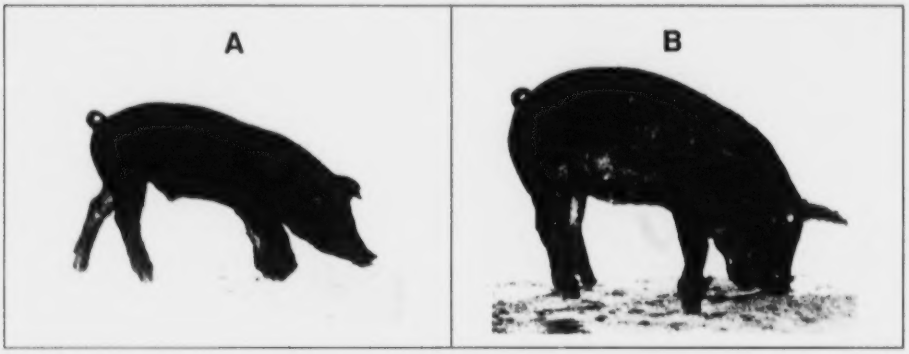
The essential and nonessential amino acids with pronunciation key

| Essential Amino Acids | | Nonessential Amino Acids |
|---|---|---|
| Methionine *(meth-eye'-o-neen)* | M* | Hydroxy-glutamic acid *(hy-drox'-ee gloo'-tam-ik)* |
| Arginine *(ar'-jeh-neen)* | A | Cystine *(sis'-teen)* |
| Tryptophan *(trip'-toe-fane)* | T | Citrulline *(sit'-roo-leen)* |
| Threonine *(three'-o-neen)* | T | Tyrosine *(tie'-ro-seen)* |
| Histidine *(his'-tuh-deen)* | H | Proline *(pro'-leen)* |
| Isoleucine *(eye'-so-loo-seen)* | I | Hydroxy-proline *(hy-drox'-ee-pro'-leen)* |
| Lysine *(lie'-seen)* | L | Lodogorgoic acid *(lo'-do-gor-goy'-ik)* |
| Leucine *(loo'-seen)* | L | Alanine *(al'-uh-neen)* |
| Valine *(vay'-leen)* | V | Serine *(seer'-een)* |
| Phenylalanine *(fen'-el-al'-uh-neen)* | P | Aspartic acid *(ass-par'-tik)* |
| | | Cysteine *(sis'-teh-een)* |
| | | Glycine *(gly'-seen)* |
| | | Glutamic acid *(gloo'-tam-ik)* |

* Reading down this column, you will see "MATT HILL, V.P." This may help you remember each essential amino acid by its first letter.

**Figure 29**

Pig A on the left was fed an isoleucine-deficient diet for 28 days; pig B was fed a diet with enough isoleucine. Note the marked difference in growth.
*(University of Illinois Circular 866)*




### *Ruminant Synthesis of Essential Amino Acids*

Ruminant animals such as cattle and sheep, however, ***can*** synthesize the essential amino acids. In Unit 1 we learned that the rumen of the digestive tract of ruminants contains millions of microorganisms that aid in the digestion of feed materials. These rumen microorganisms break down the amino acids in the feed, forming microbial protein. This digestive process takes place whether or not the ruminant's feed contains all the essential amino acids as long as ***nitrogen*** is adequate in the diet. The microorganisms pass from the rumen into the abomasum and then into the small intestine. In these organs the microbial proteins are digested and moved into the blood stream as amino acids.

As long as the ruminant is fed ***some*** of the amino acids, the digestive microorganisms help by synthesizing all the rest of the essential amino acids. Because of this, there is no group of essential amino acids for ruminants. Protein quality (balance of amino acids) is therefore not as important for ruminants as for nonruminants.

### *Rumen Bypass of Protein*

However, animal scientists have shown that the balance of amino acids absorbed by ruminants can be improved if microbial digestion of some protein sources is ***prevented*** in the rumen. Improved performance (higher milk production and more rapid gain in weight) occurs when amino acids are digested in the abomasum and small intestine instead of the rumen. This is known as ***rumen bypass*** of protein synthesis.

***High quality and low quality proteins*** - All feeds are commonly classified as being a source of either high quality protein or low quality protein. High quality protein sources contain all the essential amino acids required by a given livestock species. Low quality protein sources contain low percentages of several amino acids. This grouping is made according to the number, amount, and availability of each of the essential amino acids.

For example, soybean meal contains most of the essential amino acids in available form and in sufficient quantity to supplement a corn-based diet. Hence, it is considered an excellent protein supplement. In nonruminants such as swine, the protein is digested and released in the form of amino acids in the stomach and small intestine. The amino acids are then absorbed from the small intestine into the bloodstream.

Preventing microbial digestion of high quality proteins (like soybean meal) in the rumen can be done by special processing of the feed. Heat treatment of soybean meal prevents microbial digestion in the rumen to a great extent. Chemicals too have been used experimentally in treating high quality protein sources to delay protein digestion until the material reaches the abomasum.

### *Amino Acid Content of Feeds*

The amino acid content in livestock nutrient requirement and feed composition tables is usually given in percentages. Table 5 provides the essential amino acid content of six common livestock feeds.

Soybean meal, dehydrated alfalfa meal, and meat and bone meal generally contain higher concentrations of all the essential amino acids for swine. They are all examples of high quality protein sources. On the other hand, corn has a low percentage of several amino acids. Thus it is a low quality protein source. Actually, corn is included in the animal's diet as a high energy source rather than as a protein source.

---

**Table 5**

Percentages of essential amino acids in six livestock feeds (dry basis - 100% DM)

| Essential Amino Acids | Yellow Corn % | Oats % | Grain Sorghum % | 44% CP Soybean Meal % | Dehydrated Alfalfa - 17% Prot. % | 50% CP Meat and Bone Meal % |
|---|---|---|---|---|---|---|
| Methionine | 0.19 | 0.19 | 0.15 | 0.58 | 0.29 | 0.70 |
| Arginine | 0.48 | 0.79 | 0.43 | 3.38 | 0.84 | 3.75 |
| Tryptophan | 0.09 | 0.17 | 0.12 | 0.71 | 0.37 | 0.32 |
| Threonine | 0.40 | 0.40 | 0.40 | 1.85 | 0.77 | 1.77 |
| Histidine | 0.29 | 0.21 | 0.26 | 1.19 | 0.36 | 1.04 |
| Isoleucine | 0.39 | 0.49 | 0.50 | 2.27 | 0.88 | 1.76 |
| Lysine | 0.28 | 0.44 | 0.28 | 2.99 | 0.93 | 3.11 |
| Leucine | 1.37 | 0.91 | 1.60 | 3.65 | 1.39 | 3.29 |
| Valine | 0.50 | 0.63 | 0.58 | 2.25 | 0.96 | 2.63 |
| Phenylalanine | 0.54 | 0.58 | 0.62 | 2.36 | 0.87 | 1.83 |

(Excerpted from *United States - Canadian Tables of Feed Composition*, Third edition, Table 4)

—— See NRC tables for information on additional feeds. ——

## *Crude vs. Digestible Protein in Feed*

The protein content of feed materials is given in feed composition tables as crude (total) protein, and occasionally as protein equivalent – N X 6.25.

***Crude protein*** is the total amount of protein contained in a given feed. To determine this, first chemical analysis is used to determine the nitrogen percentage. Then the nitrogen percentage is multiplied by 6.25 (because protein contains 16% nitrogen; 100% ÷16% = 6.25). This is the way to measure crude protein.

***Digestible protein*** is the part of crude protein that can be digested by an animal. This is useful mainly when working with the ***total*** diet rather than with individual feeds. Livestock nutrition experts have determined the digestible protein content of various diets by using the following experiment.

1. Animals are placed in digestion trial stalls.
2. The feed supplied to each animal is carefully weighed and recorded (Figure 30).
3. An apparatus attached to the animal enables the nutritionist to collect all the feces (Figure 31).

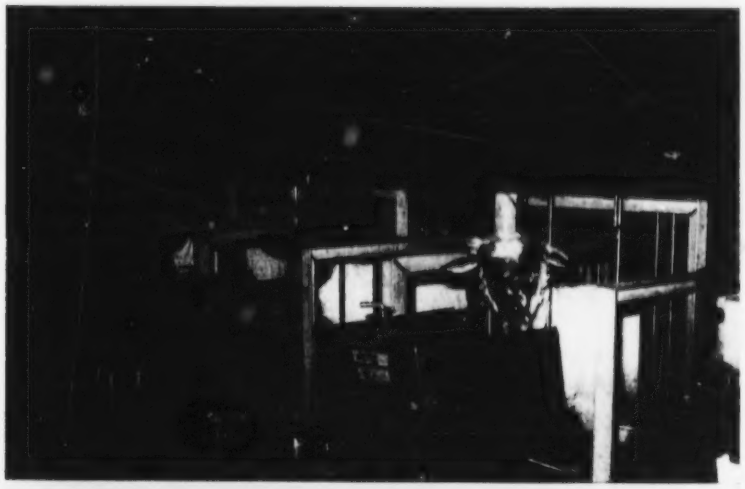


**Figure 30**

Feed is supplied to each sheep in these digestion trial stalls. *(Ohio Agricultural Research and Development Center, photo courtesy of Janice Bowman)*

**Figure 31**

Dairy cows equipped with digestion trial devices for collecting feces. *(Ohio Agricultural Research and Development Center, photo courtesy of W. Weiss)*



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4. Over a two- to three-week period the feces are collected and analyzed for nitrogen content. The amount of nitrogen found in the feces is multiplied by 6.25 to give the amount of protein. The amount of protein voided in the feces is subtracted from the crude protein consumed. The difference is the ***digestible crude protein*** content.

Both roughage feeds and concentrate feeds can vary widely in the digestibility of their crude protein. Some feedstuffs naturally withstand protein digestion, while others are easily digested. The quality of particular feedstuffs may also affect the digestibility of the crude protein they contain. A comparison of the crude protein digestibility of three common feedstuffs is given in Table 6.

**Table 6**

Three common feedstuffs compared as to crude protein digestibility.

| Feedstuff | % CP | % DP | % of CP that is digestible |
|---|---|---|---|
| orchardgrass hay, early bloom | 15.0 | 8.2 | 55% |
| corn grain, grade 2 | 10.1 | 6.5 | 64% |
| brewer's grains | 29.4 | 21.5 | 73% |

## *Protein for Nonruminant Animals*

### *Swine*

Protein that the hog requires must be in the form of amino acids which are used in building body tissue. As discussed previously, ten of the amino acids are known to be essential to swine. They must be included in the diet in concentrations high enough to meet the hog's needs. Therefore, feedstuffs used in formulating swine diets must be balanced for specific amino acids.

Swine diets are formulated using the lysine and total amino acid concentrations of the various feed ingredients. Corn-soybean meal diets (and all others) must meet the requirement for the first limiting amino acid – lysine. Because the difference between crude protein and digestible content is rather constant (80 percent), *crude protein* can be used in calculating swine diets.

### *Horses*

There is little information available on the protein digestibility of individual feeds in the horse diet. The horse can be fed a wide range of roughages, and its digestive system can handle large amounts of roughage. But, as with ruminants, protein digestibility varies according to *where* in the digestive system it occurs. Therefore, diet formulation for horses too should be based on *crude protein*.

## Water

Water is one of the most vital substances in animal nutrition. Animals can survive much longer without feed than they can without water. They generally consume three or four times as much water as feed.

Farm animals need a source of fresh, clean water available at all times. One watering device, shown in Figure 32, provides water year-round for farm animals such as cattle and horses.

The average water content of an animal's body ranges from about 70 percent at birth to about 50 percent at maturity. Very fat animals have a water content below 50 percent of their body composition (Table 7).

**Table 7**

Body water content in livestock at different ages

| Age Range | Cattle | Sheep | Swine |
|---|---|---|---|
| Birth | 75-80% | 80% | 80% |
| 5 months | 66-72% | --- | --- |
| Maturity | 50-60% | --- | --- |
| Very fat | 50% or less | 50% | 40% |

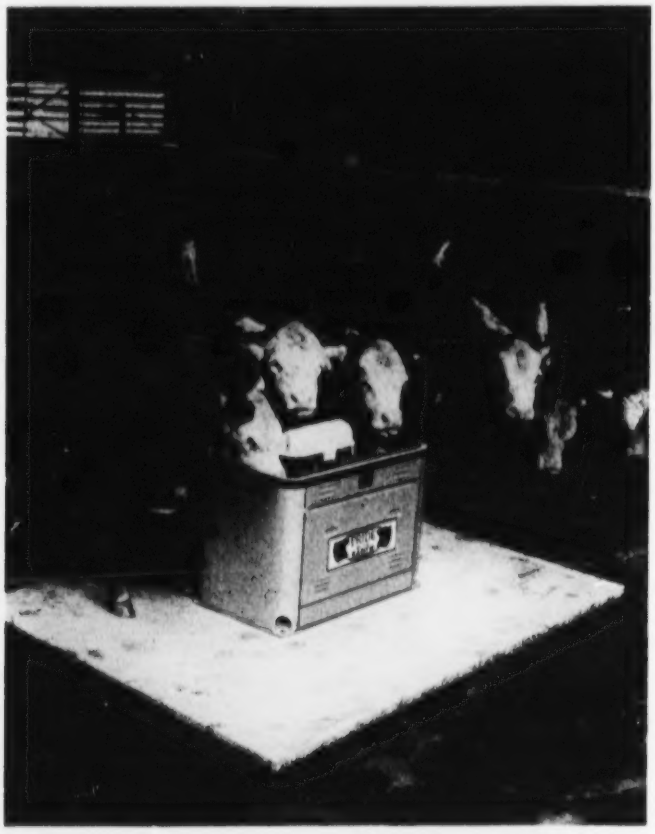


**Figure 32**

Livestock must be provided a constant supply of fresh, clean water. The watering device shown is electrically heated so that a constant supply of water will be available during the cold months of the year. *("Pride of the Ranch" livestock watering equipment, Hawkeye Steel Products, Inc.)*

## *Functions of Water*

Water performs many functions in the body, such as the following:

- It aids in body temperature regulation.
- It aids digestion, absorption, and metabolism.
- As part of the bloodstream, water transports nutrients within the body.
- As part of body composition, water helps maintain body shape.
- Water aids in elimination of waste products from the body.
- Water transfers chemicals in feeds to the taste buds where they are "recognized" by the animal.
- Water plays an important part in the exchange of gases during respiration. Water vapor is given off during respiration.
- Water cools the skin by evaporation. (Animals do not have sweat glands like humans do.)
- Through the circulatory system, water transfers heat generated in one part of the body to another part.
- Water is an important part of the body fluids that:
  - lubricate the joints,
  - act as a water cushion for the nervous system,
  - conduct sound in the ear, and
  - lubricate the eye.
- Water dilutes urea, a toxic substance that is the end product of the digestion of protein. With enough water added, urea becomes harmless to the urinary tract.

## *Sources of Water*

Water is available to animals from the following sources:

1. As drinking water
   Fresh, clean water is so important for production that it should be provided free choice at all times (if possible).

2. In feed
   Feeds contain varying amounts of water (Figure 33). Green forages such as lush-growing pasture grasses often contain 80 percent or more water. Forages harvested as silage may have up to 75 percent water content. Forages harvested as hay may have 15 percent or less water content. Most grains, such as corn, contain about 10 to 15 percent water.

3. From body metabolism
   Water is produced when carbohydrates, fats, and proteins are metabolized in the body. However, this water is not practical to consider when determining an animal's need for water.

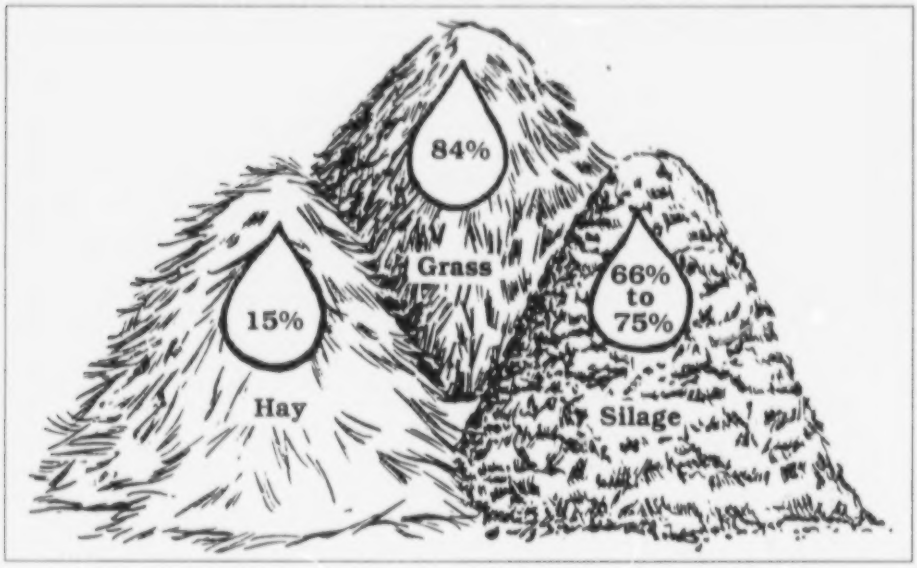
## *Water Requirements*

The drinking water requirements of any given livestock depend upon:

- age - Young animals' bodies not only have a higher water content but also a higher water requirement than mature animals.
- species
- level and kind of production
- lactation - Milk contains 87 percent water; lactating females require much more water than non-milking females do.

**Figure 33**

Difference in moisture content of grass crop harvested three ways. **One pound** of hay contains about the same dry matter as **three pounds** of silage.




- temperature - High temperatures increase the animal's water consumption.
- humidity
- amount of exercise
- type of diet - High water content in feeds reduces the free water requirement of livestock.
- mineral content of diet - Mineral consumption increases water needs.

With so many factors affecting the amount of water consumed by livestock, it is impossible to give exact daily requirements. Table 8 gives average daily water consumption for different livestock species at different levels of activity. These figures do not take into account extremes in weather conditions.

### *Effect of Lack of Water*

When water taken into an animal's body fails to meet the needs of body processes, the body cells lose water. This causes dehydration. Dehydration results in poor growth and production. If the condition is not corrected, death of the animal will occur. Important causes of water loss are ***perspiration, respiration,*** and ***scours***. Perspiration removes excess heat from the animal's body. Moist air is exhaled during the process of respiration. Scours is a digestive disturbance causing excessive water loss through diarrhea.

Animals with low water intake:

- eat less feed
- experience thickening of the blood
- lose body weight
- have reduced performance and production
- may die from dehydration

**Table 8**

Daily water consumption of livestock at different weights

| Species | Weight (lb) | Activity | Average water consumption (gal) |
|---|---|---|---|
| Beef cattle | 100 | Growing | 1.5 |
| | 400 | Growing | 5.0+ |
| | 800 | Growing | 7.0+ |
| | 1,100 | Fattening | 9.0 |
| | 1,400 | Milking | 10-15 |
| Dairy cow | | Lactating | |
| | | Aver. production | 12-25 |
| | | Heavy production | 35 |
| Sheep | 20 | Growing | 0.5 |
| | 50 | Growing | 0.4 |
| | 150-200 | Growing | 1.0+ |
| Swine | 60-80 | Growing | 1.0+ |
| | 80-125 | Growing | 1.5+ |
| | 200-400 | Pregnant | 5.0+ |
| | 200-400 | Lactating | 6.0+ |

## *Excretion of Water*

Water leaves the body by three routes:

1. In urine
   Water-soluble products of metabolism are eliminated from the body in urine. Generally, diets high in protein and minerals increase the amount of urine.

2. In feces
   All feces contain water. The amount is highly variable depending upon the species (sheep manure contains less water than does cattle manure) and the demands of production (milk production requires large amounts of water).

3. From lungs and skin
   The body loses water by perspiration from the lungs and through the skin. This cools the body by evaporation. Animals without sweat glands pant to cool their bodies.

### *Supplying Water*

Usually water is the least costly "nutrient" to supply. Whenever possible, animals should have free access to clean, fresh water at all times. "Free access" implies that animals will not have to travel great distances or overcome obstacles in order to reach their source of water. They will limit their water intake if discouraged by distance or obstacles.

During cold, freezing weather, water may need to be heated to prevent freezing (Figure 32). Animals will limit their intake of very cold water and will drink less than they need to maintain their health and productivity.

Water should be kept fresh and clean at all times so that it is palatable to the animals. When it is fresh, they are more likely to consume amounts of water that are adequate to maintain their health and productivity. Feed material, bedding, manure, and all other foreign materials should be kept out of the water at all times. Animals kept in confinement should not be able to get into their water supply with manure-covered feet. Dirty water often reduces intake and spreads diseases and parasites.

A self-watering device used in hog barns releases water as the animal nuzzles the spigot (Figure 34). This eliminates the open, contaminated bowl or trough.

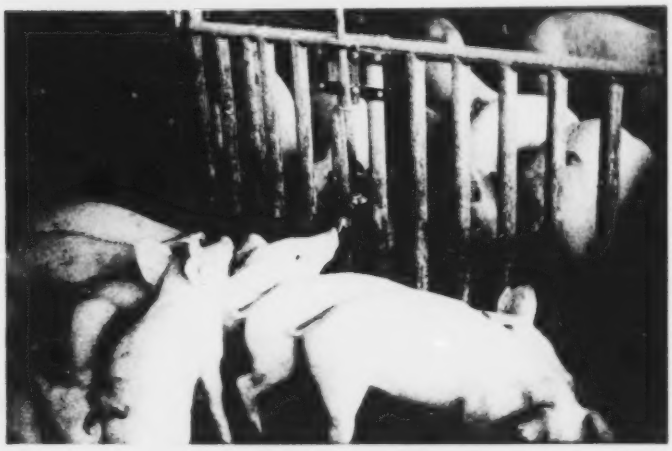


**Figure 34**

A self-watering device in a hog barn. *(Photo courtesy of Janice Bowman)*

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## Minerals

Minerals are generally needed in small amounts. However, they play an important part in the nutrition of farm animals (Figure 35). About 40 minerals occur in the tissues of plants and animals. Of these 40, the dietary-essential minerals are those that have been shown by feeding trials to have essential roles in the functioning of the animal's body.

The mineral content of a feedstuff is determined by heating it until all the organic matter in the feedstuff is burned away. The ash that is left after burning is the mineral content of the feedstuff.

**Figure 35**

A mineral block provided for cattle in a pasture field. *(Photo courtesy of Janice Bowman)*

## *Functions of Minerals*

In the animal's body, minerals:

- furnish the structural material for teeth and bones
- aid in the building of body tissues
- aid in the digestion of food (making up part of enzymes)
- aid in the regulation of many body processes (making up part of hormones)
- are a part of body fluids
- aid in the transmission of messages through the nervous system
- aid in muscle activity

## *Macro- and Micro-Minerals*

Approximately 2 to 5 percent of an animal's body is composed of minerals. There are 16 minerals which are considered essential. These are separated into two groups: 'macro' or ***major***, and 'micro' or ***trace***. Macro-minerals are generally described in quantities of pounds, kilograms, or percent of a diet. Micro-minerals are described in quantities of grains, milligrams, or parts per million and are required in very small amounts (Figure 36). Table 9 gives a list of essential macro- and micro-mineral elements.

**Table 9**

Macro- and micro-mineral elements essential to animal nutrition

| Macro- (Major) | Micro- (Trace) |
|---|---|
| calcium | copper |
| phosphorus | iodine |
| sodium | iron |
| chlorine | manganese |
| potassium | zinc |
| sulfur | cobalt |
| magnesium | selenium |
| | molybdenum |
| | chromium |
| | fluorine |
| | silicon |

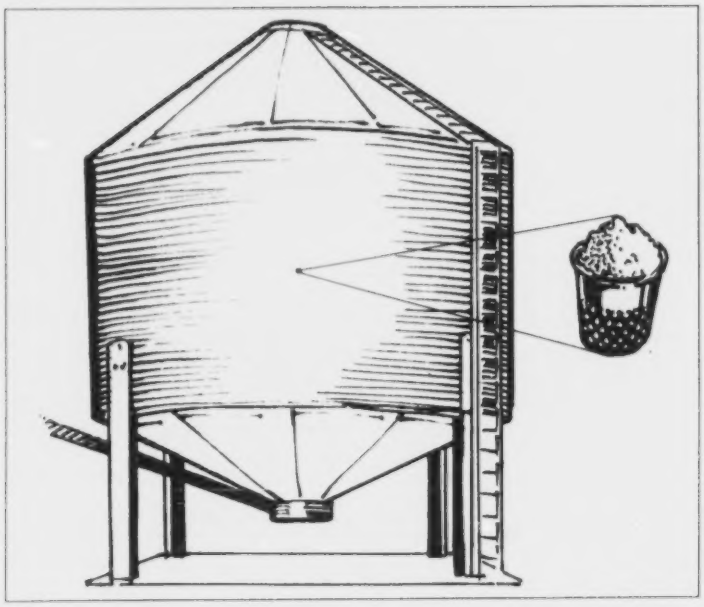

**Figure 36**

Trace or micro-mineral elements are essential for the normal growth and development of livestock. Although required in extremely small amounts (like a thimble compared to a silo), they must be present in the diet.

## Macro- Mineral Elements

### *Calcium and Phosphorus*

Calcium and phosphorus make up about 70 percent of the minerals in an animal's body. Their major function is formation of bones and teeth. The two minerals depend upon each other and also require Vitamin D before they can be used properly in the animal's body (Figure 37).

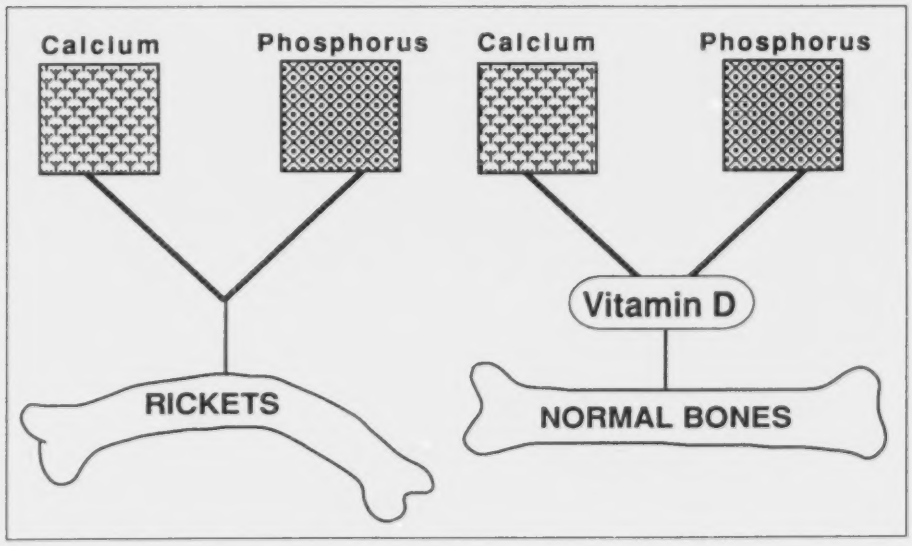


**Figure 37**

Normal bones are developed only when Vitamin D is present.

***Calcium Functions***

Calcium is vital to:

- bone and teeth formation;
  99% of body calcium is in the bones and teeth.
- nerve and muscle function
- blood coagulation
- milk production
- control of digestive enzymes

Calcium deficiency results in serious health problems. Contrast the two pigs shown in Figure 38: one that was fed a calcium-deficient diet, and the other that was fed an adequate calcium-enriched diet. Animals suffer from rickets when fed a diet seriously deficient in calcium and/or phosphorus. Fractured vertebrae and loss of control of the hind legs are common characteristics of this nutritional disease. Figure 39 shows broken hips of two cows fed calcium-deficient diets.

***Phosphorus Functions***

Phosphorus is vital:

- to bone and teeth formation; 80% of body phosphorus is in the bones and teeth.
- as part of the protein in body tissues
- as part of the blood
- to milk production
- in different metabolic processes

Illustrations of phosphorus deficiency in calves are given in Figures 40 and 41. Figure 40 shows a calf chewing on wood, a clear sign of phosphorus deficiency. The calf in Figure 41 is suffering from rickets caused by a lack of phosphorus in the diet.

---

**Figure 38**

Calcium deficiency (rickets). The young pig on the left (A) was fed a diet seriously deficient in calcium. Note the weakened and deformed bone structure of hind legs, depressed growth, and general lack of thriftiness. A normal litter mate (B) is on the right. *(University of Illinois)*

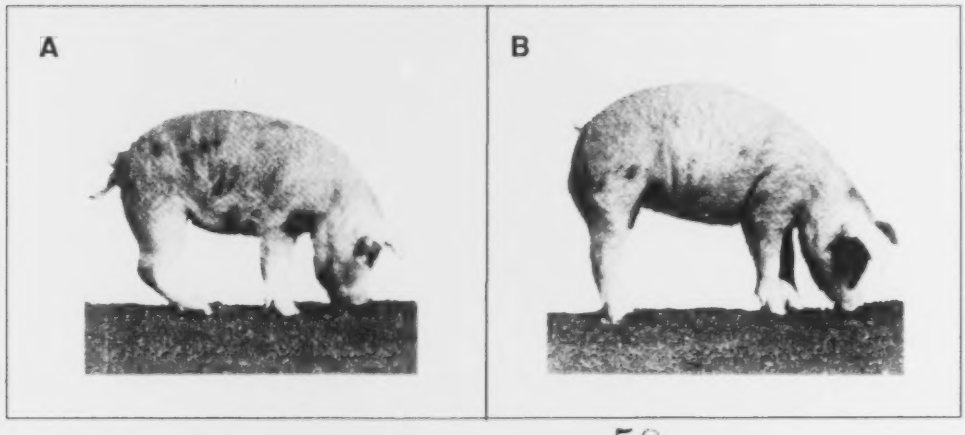




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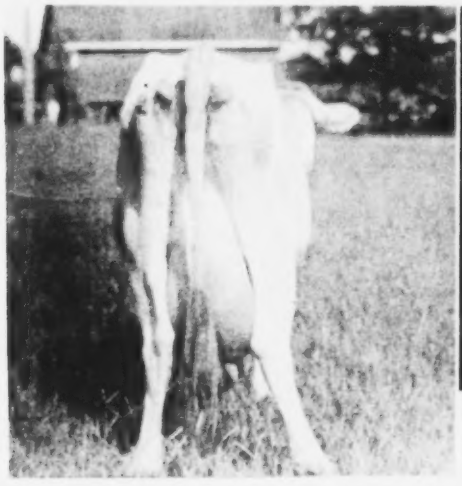
**Figure 39**

Both hips of the cow shown on the left have been broken ('knocked down') as a result of being fed a low calcium diet. At the right is the pelvis of this cow, showing the nature of the breaks involving both hip bones. In the center is the pelvis of another cow which suffered three breaks while on a low calcium diet. *(Florida Agricultural Experiment Station)*



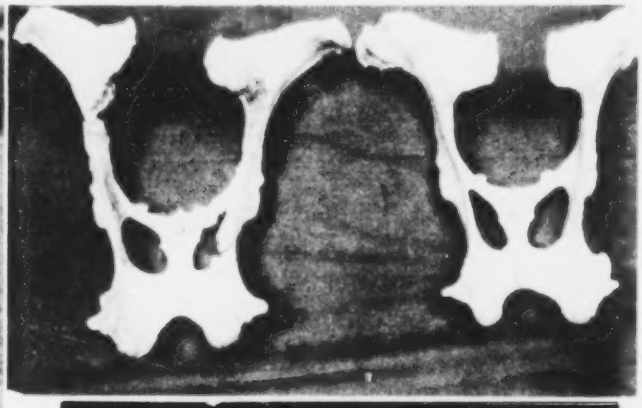


**Figure 40**

A calf that chews on wood indicates a phosphorus-deficient diet. *(Cornell Agricultural Experiment Station)*

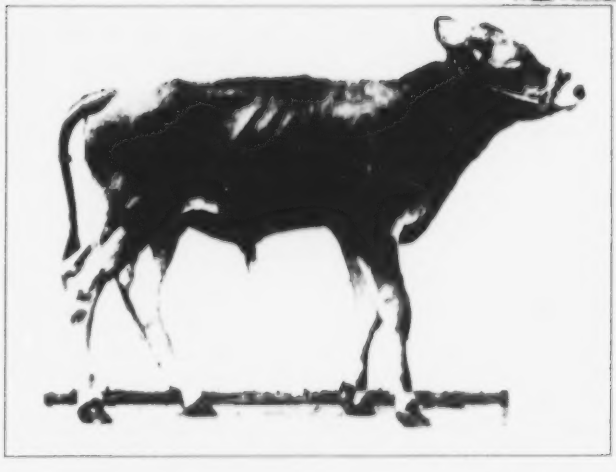


**Figure 41**

A calf suffering from rickets as a result of lack of phosphorus in the diet. *(Michigan Agricultural Experiment Station)*



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A considerable excess of either calcium or phosphorus interferes with absorption of the other element. Thus, having a suitable ratio between the two minerals is also very important.

- Ruminant animals should have a calcium to phosphorus ratio of 2-2.5 parts of calcium to 1 part of phosphorus.
- Nonruminants (swine) should have a calcium to phosphorus ratio of 1.2-1.5 parts of calcium to 1 part of phosphorus.
- Vitamin D is required for the absorption of calcium and phosphorus.

### *Sodium and Chlorine (Common Salt or NaCl)*

The two elements sodium (Na) and chlorine (Cl) combine to form the compound salt (NaCl). Together they control the concentration of body fluids within cells and the fluids' movement into and out of cells by osmosis. Figure 42 provides information about the average monthly consumption of salt by farm animals.

#### *Sodium Functions*

Sodium is vital in:

- transfer of nutrients to cells
- removal of water from cells
- maintaining water balance in body tissues
- muscle contraction
- manufacture of bile

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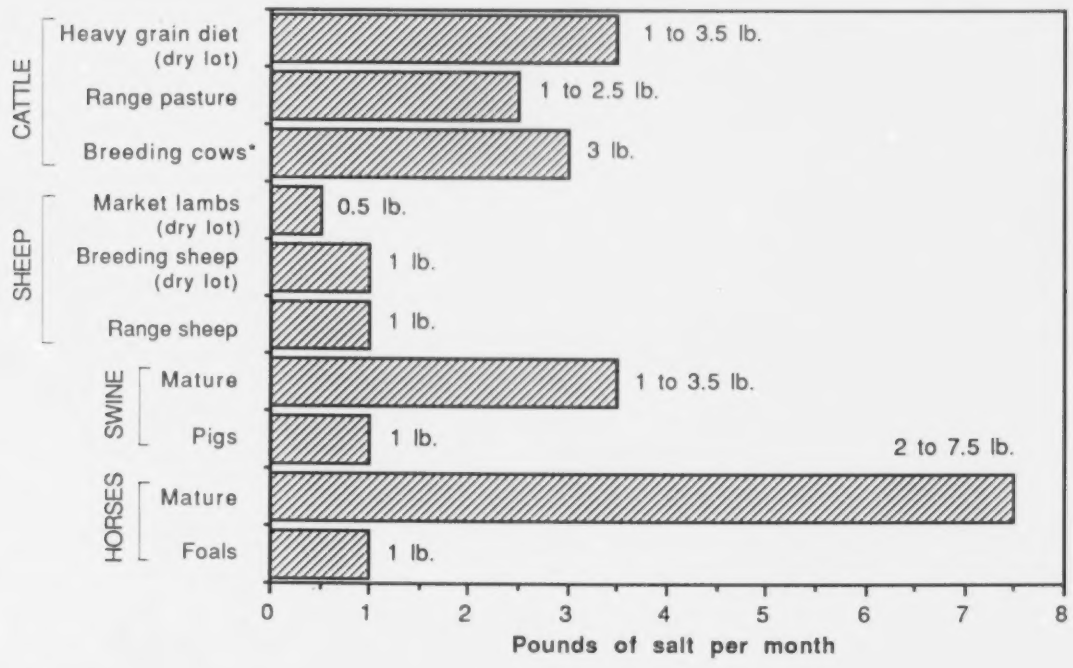
**Figure 42**

Average monthly consumption of salt by farm animals.



### *Chlorine Functions*

Chlorine is vital in:
- formation of digestive juices
- formation of hydrochloric acid in the stomach, an important part of protein digestion

### *Potassium, Sulfur, and Magnesium Functions*

Most of the ***potassium*** functions inside the body cells by:
- assisting in the control of body fluid concentration and movement into and out of cells
- assisting in the digestion of carbohydrates and protein
- being necessary for muscle activity

***Sulfur*** is essential in the body for:
- synthesis of sulfur-containing amino acids in the rumen
- use by the rumen of non-protein nitrogen (urea) in the diet
- fiber digestion
- production of non-volatile fatty acids

***Magnesium*** is closely associated in the animal's body with calcium and phosphorus.
- About 70% of the total amount of magnesium is found in bones and teeth.

Magnesium is also vital in:
- enzyme formation and function in the body
- carbohydrate metabolism
- proper functioning of the nervous system
- preventing destruction of body cells

## Micro- Mineral Elements

As previously mentioned, micro-mineral elements are required in very small amounts, hence the term "trace" minerals. They are nevertheless essential for animal growth and development.

Most trace minerals are found in adequate amounts in good quality roughages and some concentrate feeds. The quantity of each trace mineral is determined to some extent by the mineral content of the soils on which they are grown. Mineralized salt is a supplemental source of trace minerals. For ruminants it is often fed free-choice. For swine it is usually mixed with the feed.

The following micro-mineral elements are ones that *may* be deficient in the animal's diet. Fluorine, chromium, and silicon also are essential for the animal's health and productivity but are not likely to be deficient in the diet. Micro-minerals fed in excess of the animal's needs can be highly toxic, so supplementing trace minerals should be done with extreme care.

- ***Copper*** is required in trace quantities to enable the animal to absorb the iron in its diet.

- ★ ***Iodine*** is necessary for the formation of the hormone thyroxine. This compound is produced by the thyroid gland and secreted into the bloodstream. A lack of sufficient iodine in the diet causes goiter in animals. Pigs may be born weak or hairless if the brood sow diet is deficient in iodine.

- ★ ***Iron*** is part of the pigment hemoglobin. Hemoglobin increases the oxygen-carrying capacity of the blood. A deficiency of iron causes nutritional anemia in animals.

- ★ ***Manganese*** is essential to proper growth and development of animals. Manganese deficiency can result in decreased growth rates and can cause reproductive problems.

- ★ ***Zinc*** is a part of 30 different enzymes required for metabolism and protein synthesis. One of these is the respiratory enzyme *carbonic anhydrase* which is found in red blood cells and other parts of the animal's body. Carbonic anhydrase is required for the process of carbon dioxide elimination from the body. A zinc-deficient diet results in *parakeratosis*, a condition in which growth is reduced and hair development is retarded, giving a very harsh and dry hair coat (Figures 43 and 44). A dark brownish secretion is often found on the fore and hind legs, hams, and belly of hogs with parakeratosis.

- ★ ***Cobalt*** is required for the microorganisms of the rumen to function. Without this mineral, microorganisms cannot multiply and grow or help break down the fiber in the feed. Also, ruminants are unable to synthesize Vitamin $B_{12}$ without cobalt.

- ★ ***Selenium*** is essential to protection against breakdown of cells and tissues. It is also necessary for normal functioning of the pancreas and for proper absorption and use of Vitamin E.

- ★ ***Molybdenum*** is required for various enzymes to function.

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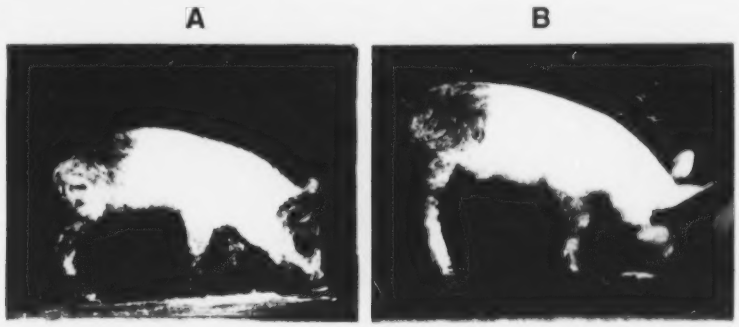
**Figure 43**

The pig on the left (A) was fed a zinc-deficient diet which resulted in parakeratosis. Contrast this with (B), a litter mate that was fed the same diet, but with supplementary zinc. Note the clean, smooth hair coat, normal body conformation, and improved growth. *(University of Illinois)*



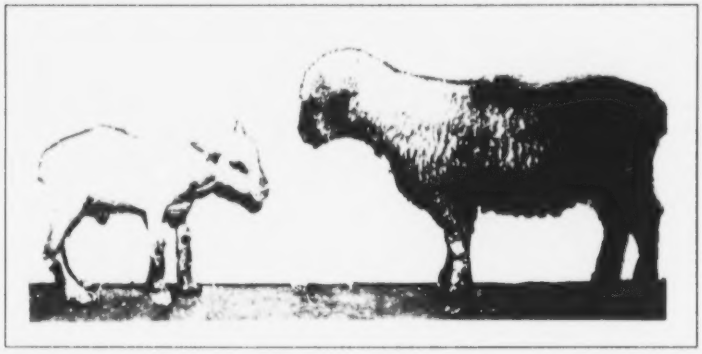


**Figure 44**

The deficient lamb on the left received a diet containing only 3 ppm zinc. The normal lamb on the right received a diet containing 100 ppm zinc. *(Purdue Agricultural Experiment Station)*

## Vitamins

All the food nutrients described in this unit ***except vitamins*** become part of the animal's body during the process of metabolism. Vitamins alone do not become part of the body, but they serve to regulate the various body functions. They are like the umpire or referee of a ball game. They are not actual players of the game, but the game could not go on without them. Hence, vitamins do not enter into the body process. Instead, they act as catalysts in the many chemical reactions that take place in the animal's body.

### *Functions of Vitamins*

Vitamins are necessary in:

- regulating the processes of digestion, absorption, and metabolism
- regulating the activities of the glands
- regulating the formation of new cells which promote growth and maintenance
- development of normal and healthy bones, skin, hair or wool, and muscles
- development of normal vision
- protection against diseases
- development and maintenance of a healthy nervous system

Each vitamin has its own functions. The vitamin needs of a given farm animal depend upon its age and productive function.

### *Classification of Vitamins*

Vitamins can be divided into two general categories: fat soluble and water soluble vitamins (Figure 45). The ***fat soluble vitamins*** are A, D, E, and K. They dissolve in fat and during the digestive process are found in fat. The ***water soluble vitamins*** are C and those of the B complex. These vitamins dissolve in water and during the digestive process are found in water.

#### Fat Soluble Vitamins - A, D, E, and K

These vitamins contain the elements carbon, hydrogen, and oxygen. They are generally responsible for regulating the use of other food nutrients in the body.

**Figure 45**

Vitamins may be classified as either **fat soluble** (A, D, E, and K) or **water soluble** (C and the B complex vitamins).

***Vitamin A*** is required for:

- maintenance of the epithelial tissues of the body. (The epithelium is the tissue covering the outside surface of the body and the lining of such body cavities as the digestive tract and lungs.)
- good vision
- reproduction
- disease resistance
- bone development
- normal growth and weight gain

Blindness and other abnormalities can result from Vitamin A deficiency in the diet (Figure 46).

***Vitamin D*** is essential in the absorption of calcium and phosphorus from the intestines. Because of this, Vitamin D is required for:

- good bone growth in young animals. (The disease ***rickets*** is a result of the lack of Vitamin D.)
- prevention of osteomalacia in older animals. (This disease results in softening and fracturing of the bones.)

**Figure 46**

A litter of pigs showing Vitamin A deficiency. Blindness and other abnormalities resulted. *(Texas Agricultural Experiment Station)*

As mentioned previously, a lack of calcium and phosphorus in the animal's diet causes the same symptoms since Vitamin D and calcium and phosphorus are interdependent (Figure 37). Both Vitamin D and Vitamin A are plentiful to animals supplied with green feed and sunshine (Figure 47).

***Vitamin E*** is required for:

- prevention of muscular diseases in young animals (diseases such as muscular dystrophy or white muscle disease)
- normal reproduction
- normal growth
- absorption and storage of Vitamin A in the body; (thus, a shortage of Vitamin E may also cause a shortage of Vitamin A.)

There is also a link between Vitamin E and the micro-mineral selenium. In soils that have a low selenium content, addition of selenium to the diet helps to improve the animal's use of Vitamin E.

***Vitamin K*** is required for clotting of blood. Lack of Vitamin K can result in excessive bleeding.

Moldy feeds may cause a deficiency of Vitamin K. Also, moldy sweet clover hay may cause hemorrhage of blood vessels in ruminants. This is caused by dicumerol, which is concentrated in moldy sweet clover hay. Dicumerol acts in opposition to Vitamin K.

All farm animals except poultry synthesize Vitamin K in their digestive tract.

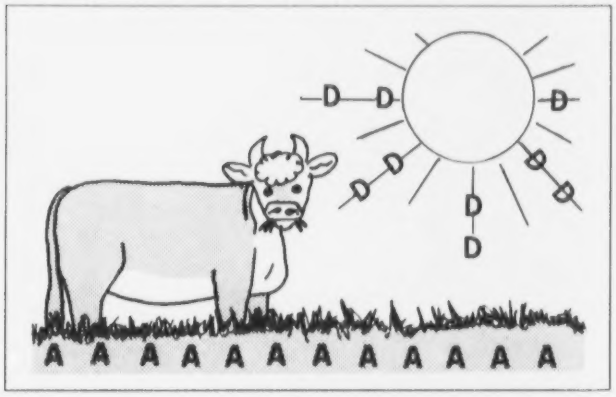



**Figure 47**

Vitamins A and D occur in abundance when farm animals have access to green feed and sunshine.

### Water Soluble Vitamins C and B-Complex

Water soluble vitamins contain carbon, oxygen, nitrogen, chlorine, and sulfur or cobalt. They are generally found in all tissues of the body.

#### *Functions*

Water soluble vitamins are necessary to:

- regulate the use of energy in the body
- develop and maintain the nervous system

- promote growth
- aid in reproduction

The functions of water soluble vitamins are so interdependent that it is often difficult to identify the deficiency causing given symptoms.

***Vitamin C*** has been shown to be present in sufficient amounts in most diets. It is also synthesized (manufactured) in the body tissue of farm animals.

$B_1$ thiamine
$B_2$ riboflavin
niacin
$B_6$ pyridoxine
inositol
$B_{12}$ cobalamin
pantothenic acid
folic acid
biotin
choline

The ***B-complex vitamins*** are a group of ten different vitamins:

Ruminants usually do not need supplemental B vitamins. (There are a few cases, however, where supplemental niacin is needed.) As explained in Unit 1, the microorganisms in the rumen break down feed materials and form the B-complex vitamins. They are then absorbed into the bloodstream from the rumen and small intestine.

A similar process takes place in the cecum of the horse. However, the process is not as efficient as with ruminants. If the diet is of high quality, no supplemental B vitamins should be required. But if the diet is of low quality, some of the B vitamins may need to be supplemented.

Nonruminants such as swine cannot manufacture (synthesize) many of the B vitamins in their digestive tracts. They must obtain B vitamins from their feed. The B vitamins that must usually be supplemented in swine diets are riboflavin, niacin, thiamine, pantothenic acid, and $B_{12}$. Deficiency symptoms of two of these vitamins are shown in Figures 48 and 49.

## Air

Air furnishes the oxygen that is used in an animal's body to oxidize (burn) the carbon and hydrogen contained in the animal's feed. This oxidation is part of the metabolic process that provides the energy for work and production. Air also ventilates the body, carrying away noxious gases.

When livestock are confined, the quarters must be well ventilated so that fresh air containing oxygen is available. Animals give off carbon dioxide, water, and other gases as they breathe. This reduces the oxygen content of the air unless continuous fresh air is provided by ventilation.

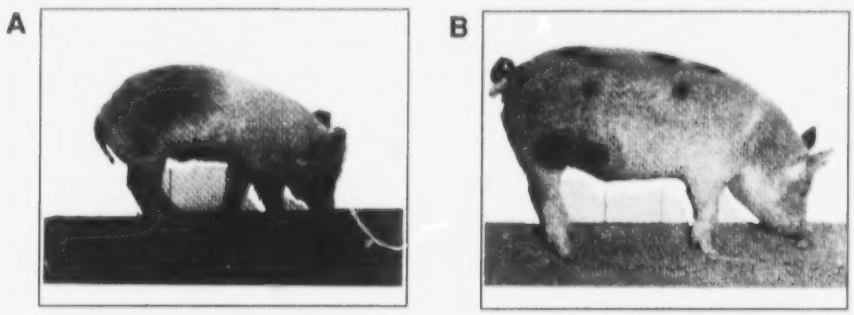
Also, on very hot, humid, windless days in the summer, animals may have trouble getting enough fresh air. At such times, livestock should be provided shade in locations that encourage air movement. Or they should be housed in areas where forced air ventilation is provided.

**Figure 48**

Pantothenic acid deficiency. Locomotor incoordination (goose-stepping) was produced by feeding a corn-soybean meal diet low in pantothenic acid. *(Michigan Agricultural Experiment Station)*

**Figure 49**

The pig on the left (A) was fed a high corn diet without supplementary niacin. This pig grew slowly, exhibited a rough hair coat, and had intermittent diarrhea. Its intestinal tract was later found to be ulcerated. The pig on the right (B) was healthy, fed a high corn diet containing enough niacin.




## BODY USES OF FOOD NUTRIENTS

The three basic functions which food nutrients serve in the animal's body (shown in Figure 50) are as follows:

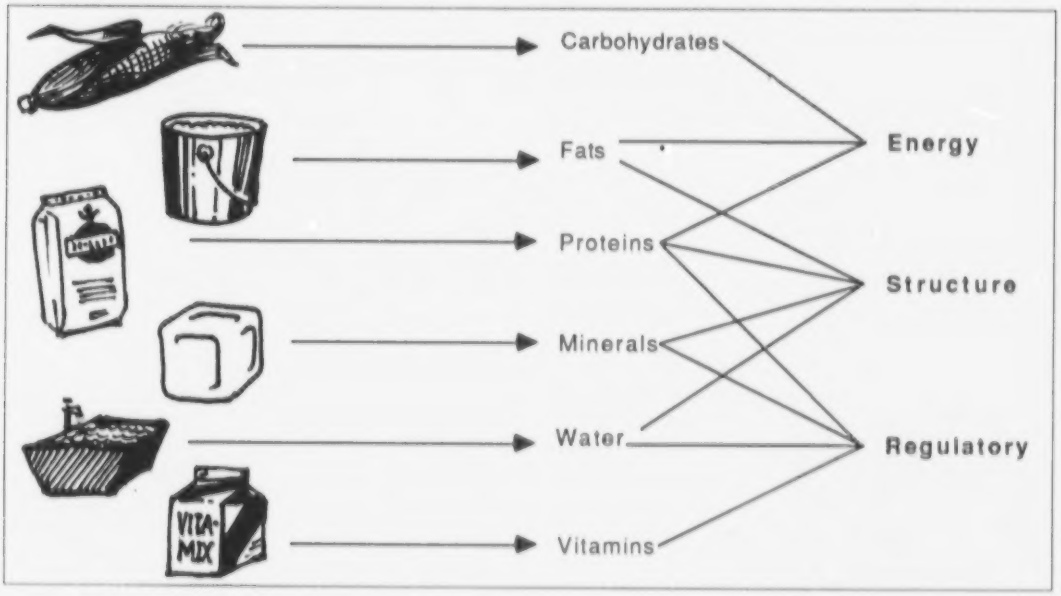
- ★ providing energy
- ★ building structure
- ★ regulating body functions

### *Energy*

The term *energy* is used to describe the end product or power produced when energy-producing feeds are consumed and metabolized by livestock. Energy is defined as the heat of combustion and is measured in ***calories per pound*** of feed.

**Figure 50**

Food nutrients provide the body with energy, body structure, and regulatory capacity.




Carbohydrates, proteins, and fats can all be used for energy. The body uses energy:

- ★ as fuel for functioning
- ★ for warmth and movement
- ★ for the vital body activities of respiration, heart beat, blood circulation, and digestion
- ★ for growth

Lack of energy in the diet causes an animal to be unthrifty or even to die.

### *Structure*

Fats, proteins, minerals, and water are all needed for development of the animal body (or ***structure***)—its bones and teeth, protein tissues and organs, and fatty tissue.

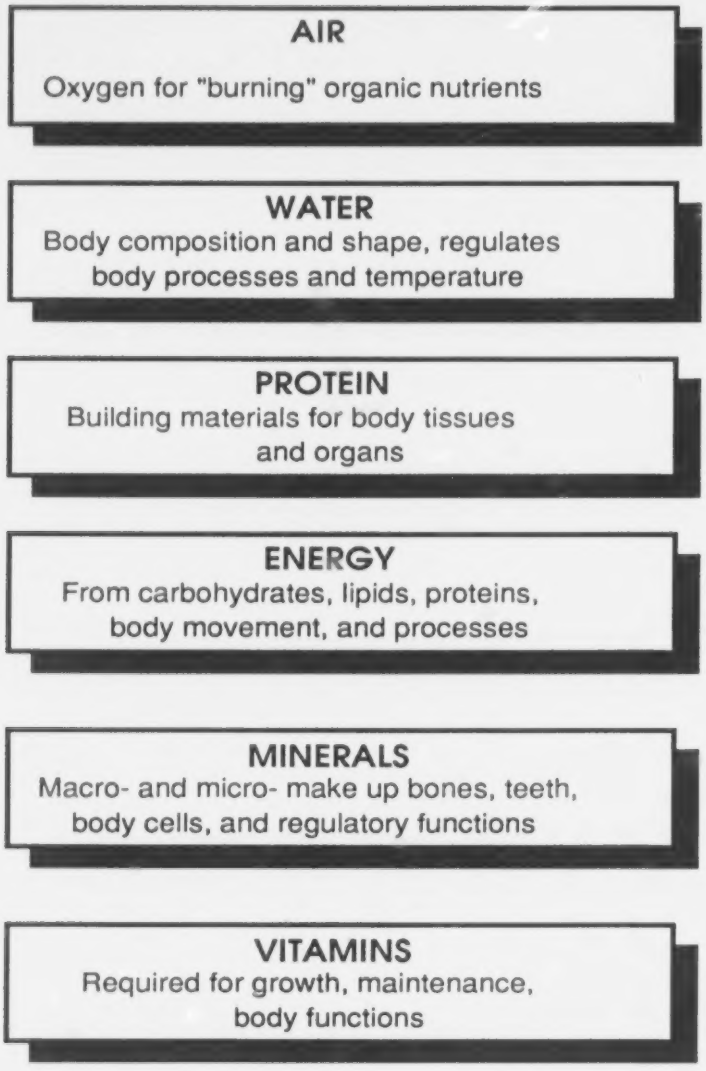
### *Regulation*

Proteins, minerals, water, and vitamins are all needed to regulate body processes.

Figure 51 lists the basic feed nutrients, including energy as a nutrient rather than listing its individual sources. The many ways that the body uses feed nutrients are shown in Figure 52.

**Figure 51**

Basic food nutrients.


AIR
Oxygen for "burning" organic nutrients
WATER
Body composition and shape, regulates body processes and temperature
PROTEIN
Building materials for body tissues and organs
ENERGY
From carbohydrates, lipids, proteins, body movement, and processes
MINERALS
Macro- and micro- make up bones, teeth, body cells, and regulatory functions
VITAMINS
Required for growth, maintenance, body functions

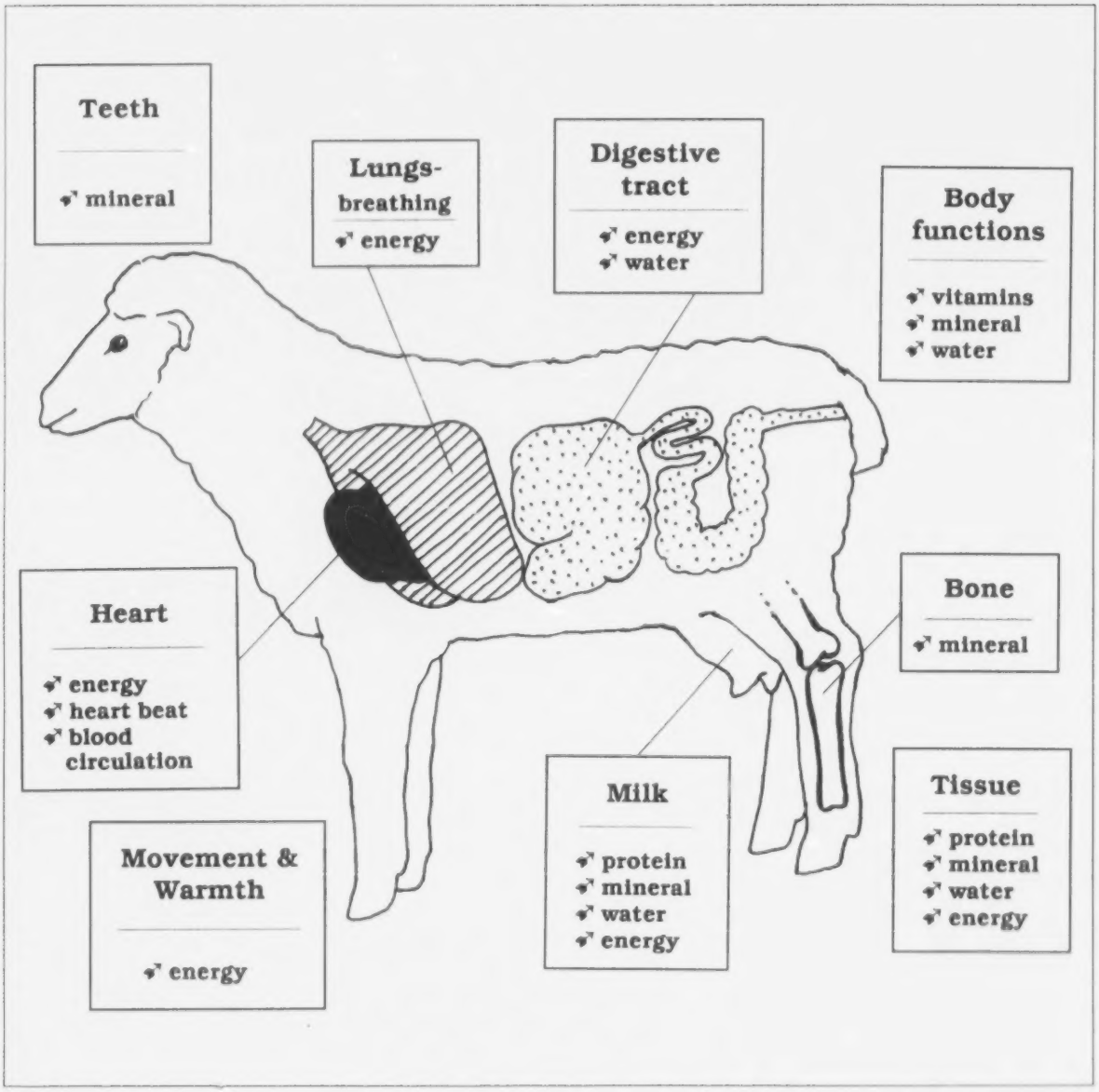
## Energy Values

We raise livestock in order to produce commodities such as meat, milk, wool, hides, and work. From this production, we hope to make a profit. To be productive, animals must get enough feed to meet their requirements for energy, protein, minerals, and vitamins. They obtain energy from carbohydrates, lipids, and proteins. They must consume all other essential nutrients directly.

Energy comprises about 70 to 80 percent of the total nutrient requirement of a diet. Thus, calculating the amount of energy for livestock is very important. Two categories of tables are available for use in formulating

Figure 52

How the body uses food nutrients.



animal diets: 1) tables of feed composition that give ***energy content*** of feedstuffs; and 2) tables of nutrient requirements that give ***energy requirements*** for different livestock species and types of activity.

The most important form of energy for livestock is chemical energy. Plants produce chemical energy with the help of solar energy. Through the process of photosynthesis, carbohydrates are manufactured.

Scientists can measure the chemical energy content of feedstuffs by using a laboratory apparatus known as a bomb calorimeter. Feed samples are burned in the bomb calorimeter and the amount of heat or energy released is measured. The result is given as kilocalories of gross energy. (See page 63.)

Chemical energy becomes available to animals as they consume and digest it. The efficiency with which energy is used for weight gain, pregnancy, and lactation usually increases as levels of energy in the diet increase. Energy needs of livestock are affected by:

- age
- body size
- growth
- condition (overly fat or thin)
- pregnancy
- lactation
- environment (temperature, humidity, sunshine, wind)
- stress
- activity level (moving about to obtain food, water, shade, shelter; or working; or not moving)

## Measures of Feed Energy

When measuring energy provided by a feed ingredient, it is important to keep in mind that the energy released from a feed is measured in calories. (See pages 63-64.) Energy measurement does not deal with specific weight in pounds or percent of protein or other nutrients contained in a given amount of feed.

Measures of feed energy are expressed as follows:

- Gross energy (GE)
- Digestible energy (DE)
- Metabolizable energy (ME)
- Net energy (NE)

(See Figure 53.)

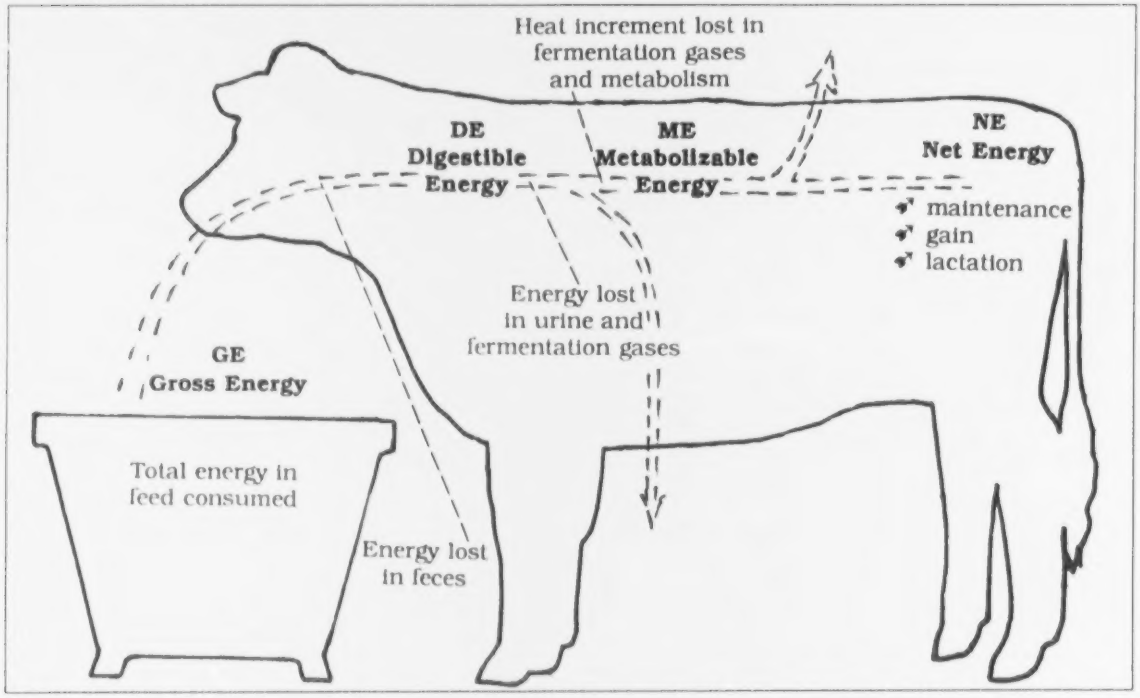
### *Gross Energy (GE)*

Gross energy is the ***total amount of energy*** in a feed. However, an animal does not have the use of all that energy. Energy is lost through metabolism, feces, fermentation gases, and urine.

Gross energy is not used directly in evaluating energy values of feeds fed to livestock. However, it can be used to compare the percentage of digestibility of the feed materials fed to different livestock species.

**Figure 53**

Calorie system of energy determination




### *Digestible Energy (DE)*

Digestible energy is the energy that is left after the loss from feces is deducted. The difference between digestible energy and gross energy varies with feed materials. Digestible energy values are used in calculating some diets for livestock. For example, *Nutrient Requirements of Horses,* a publication of the National Academy of Sciences, gives energy values only as digestible energy. Thus, in calculating horse diets, digestible energy values would have to be used.

DE = GE *minus* fecal energy

### *Metabolizable Energy (ME)*

Some energy is lost in urine and combustible gases. Metabolizable energy is determined by subtracting energy lost through urine and combustible gases from digestible energy.

ME = DE *minus* (gas energy loss + urinary energy loss)

### *Net Energy (NE)*

Net energy is the ***energy available for maintenance and production.*** The presence of food in the body causes heat production or heat increment. Heat increment is the rise in body heat caused by food digestion and metabolism. This heat can be used to maintain body warmth and has no productive value.

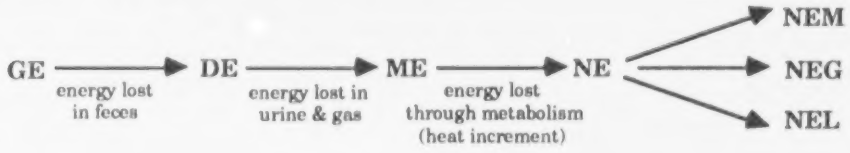
(Refer again to Figure 52.) When heat increment is subtracted from metabolizable energy, net energy is obtained. This energy is completely usable by the animal.

NE = ME *minus* heat increment

Three expressions of net energy values are:

- ★ net energy for maintenance - NEM,
- ★ net energy for gain alone - NEG, and
- ★ net energy for lactation - NEL

A simple way to show this energy loss (illustrated in Figure 53) is:




In general, forages have higher heat-increment values than do grains. Thus, animals that eat the higher fiber content diets that require more time and energy for digestion will have a greater loss of energy due to heat increment.

A good example of the different energy measurements is shown in Table 10 in the values of corn grain and alfalfa hay on a dry basis when fed to beef cattle.

| Energy | Corn Grain kcal/lb | Alfalfa Hay kcal/lb |
|---|---|---|
| GE | 1998 | 2040 |
| DE | 1800 | 1202 |
| ME | 1474 | 984 |
| NEM | 1016 | 594 |
| NEG | 703 | 336 |

**Table 10**

Energy values of corn and alfalfa when fed to cattle

## Determining Energy Requirements

### *Definitions*

As previously stated, energy contents of feed and energy requirements of livestock are measured in calories. The units of measure most commonly used for energy are:

- ★ calorie - the amount of energy as heat required to raise the temperature of 1 gram of water 1 degree C (from 14.5°C to 15.5°C)
- ★ kilocalorie, kcal - the amount of energy as heat required to raise the temperature of 1 kilogram of water 1 degree C (from 14.5°C to 15.5°C) or 1,000 calories
- ★ megacalorie, Mcal - 1,000 kcal or 1,000,000 calories

## *Shelled Corn Example of Energy Values*

Table 11 gives the gross, digestible, and metabolizable energy for shelled corn when fed to different species of farm animals.

**Table 11**

Comparison of the energy values of shelled corn when fed to swine, sheep, and cattle.

| Livestock | GE kcal/lb | DE kcal/lb | % of GE | ME kcal/lb | % of DE |
|---|---|---|---|---|---|
| Swine | 2,181 | 1,591 | 73 | 1,496 | 94 |
| Sheep | 2,181 | 1,695 | 78 | 1,390 | 82 |
| Cattle | 2,181 | 1,574 | 72 | 1,291 | 82 |

To determine how efficiently each species uses energy, use these data and follow this procedure:

1 ) The gross energy value for shelled corn is 2181 kcal/lb.

2 ) The digestible energy value for shelled corn when fed to different kinds of livestock is as follows:
swine 1591 kcal/lb
sheep 1695 kcal/lb
cattle 1574 kcal/lb

3 ) Calculate the percentage efficiency for each species by dividing the digestible energy value by the gross energy value:

*Swine*

1591 k cal/lb digestible energy (DE) value for swine ÷
2181 k cal/lb gross energy (GE) value (shelled corn) = .73 or 73% efficient

*Sheep*

1695 k cal/lb digestible energy (DE) value for sheep ÷
2181 k cal/lb gross energy (GE) value (shelled corn) = .78 or 78% efficient

*Cattle*

1574 k cal/lb digestible energy (DE) value for cattle ÷
2181 k cal/lb gross energy (GE) value (shelled corn) = .72 or 72% efficient

These figures show that sheep have the highest efficiency (78%) in converting gross energy of shelled corn to digestible energy. Swine (73%) and cattle (72%) are almost equal in their efficiency conversion values.

### *Calorie System vs. TDN System*

*Total digestible nutrients* was at one time the most commonly used value in determining energy requirements for ruminants. Total digestible nutrients include the digestible crude fiber, plus digestible fat (digestible ether extract x 2.25), plus digestible protein. Digestible crude protein is included because any excess above the animal's protein needs is used for energy. The total digestible nutrient content of thousands of feedstuffs was determined.

A disadvantage of the TDN system is that it measures energy in terms of pounds and percentages. These are not an accurate measure of the energy value of a feedstuff.

However, the ***calorie system***, by measuring heat produced, does accurately measure the energy contained in a particular feedstuff. In this manual the calorie system will be followed in formulating animal diets.

### *Component of Feedstuffs*

Some of the chemical processes used by scientists in identifying the make-up of a feedstuff were described briefly as the different nutrients were discussed. Except for air and water, each component (part) of a feedstuff contains many individual elements or nutrients as shown in Table 12.

---

**Table 12**

Components of feed

| Component | Elements or Nutrients Contained |
|---|---|
| **Air** | Oxygen and other gases in the atmosphere |
| **Water** | Water, volatile compounds |
| **Ash** | *Essential minerals*<br>Macro-minerals - calcium, chlorine, potassium, magnesium, sodium, sulfur, phosphorus<br>Micro-minerals (trace) - chromium, cobalt, copper, fluorine, iodine, iron, manganese, molybdenum, selenium, silicon, zinc<br>*Possibly essential minerals*<br>barium, bromine, nickel, strontium, tin, vanadium |
| **Crude protein** | Protein, amino acids, nucleic acids, alkaloids, nonprotein nitrogen compounds |
| **Ether extract** | Fats, oils, waxes, resins, organic acids, plant pigments, vitamins A, D, E, K |
| **Neutral detergent fiber** | Cellulose, hemicellulose, lignin |
| **Non-fiber carbohydrate** | Starch, sugars (tri-, di-, and monosaccharides), hemicellulose. In forages, small amounts of cellulose and lignin are also present. |

## *Measuring Nutrient Content of Feedstuffs*

The amount of a given nutrient contained in a feedstuff can be expressed in several ways. The unit of measure used depends on whether the nutrient makes up a large or small part of the feedstuff. Commonly used units of measure are:

***Percent (%)*** A feedstuff contains so many parts (pounds, kilograms, grams, or any other unit of weight measurement) of nutrient per 100 parts (using the same unit of weight measured) of the overall feedstuff.

*Example 1.* By chemical analysis, 100 pounds of yellow dent shelled corn contains 11 pounds of crude protein (CP). The percentage (%) of crude protein (CP) would be 11%.

11 lb + 100 lb = .11 or 11% CP

*Example 2.* 10 grams (g) of corn are analyzed and found to contain 1.1 grams (g) of crude protein (CP). The percentage (%) of CP would be 11%.

1.1 g + 10 g = .11 or 11% CP

***Parts per million*** *(ppm)* A feedstuff contains so many parts (lb, kg, g, mg, meg, or any other unit of weight measurement) of vitamin (for example) per 1,000,000 parts (using the same unit of weight measurement) of the overall feedstuff. (The difference between *ppm* and % is the location of the decimal point.)

1,000,000 = 10,000 x 100

*For example:* A feedstuff contains 3 ppm of a vitamin.

To change *ppm* to %, divide by 10,000; (move the decimal point four places to the left.)

3 + 10,000 = .0003%

To change % to *ppm*, multiply by 10,000; (move the decimal point four places to the right.)

.0003% x 10,000 = 3.000 ppm

ppm also equals milligram (mg) per kilogram (kg).

1 kg = 1,000 g
1 g = 1,000 mg
1 kg = 1,000,000 mg

***Milligrams per pound*** *(mg/lb)* A pound of a given feedstuff contains so many milligrams of an additive.

*For example:* There are 2 mg of an additive in 1 lb of feedstuff.

Since one pound equals 454,000 mg, this measurement of mg/lb is the same as 2 mg in 454,000 mg.

1,000,000 + 454,000 = 2.2 times

To change *mg/lb* to *ppm* multiply by 2.2.

2 mg/lb x 2.2 = 4.4 ppm

To change *mg/lb* to % multiply by 2.2 and divide by 10,000.

2 mg/lb x 2.2 = 4.4 ppm + 10,000 = .00044%

To change *ppm* to *mg/lb* divide by 2.2.

4.4 ppm + 2.2 = 2 mg/lb

To change % to *mg/lb* multiply by 10,000 and divide by 2.2.

.00044% x 10,000 = 04.4 ppm + 2.2 = 2.2 mg/lb

**Important biological concepts to learn from Unit 2:**

- ★ Six basic food nutrients are required by animals to maintain their bodies, carry on their body processes, be productive, and remain healthy.
- ★ Each of the six basic food nutrients has specific purposes in the animal's body.
- ★ Livestock are able to transform the six basic food nutrients into meat, milk, wool, hides, and work by the processes of digestion, absorption, and metabolism.
- ★ Animals obtain energy to carry on body processes, maintain their bodies, be productive, and move about by oxidizing carbon-containing nutrients.

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## REVIEW of Unit 2

After studying Unit 2, "The Food Nutrients," you should be able to answer and discuss the following questions.

1. Prepare the following table in your notebook and use it to organize and present information about the six basic food nutrients in nonruminants and ruminants. *(pages 30ff)*

| Name of Nutrient | Function in the Nonruminant | Function in the Ruminant |
|---|---|---|
| *Example:* **Water** | Aids in body temperature regulation.<br>Aids in digestion, absorption, and metabolism.<br>Transports nutrients within the body.<br>Helps maintain shape as a part of body composition.<br>Aids in elimination of waste products from the body.<br>Important part of body fluids. | Same as for nonruminant. |

2. What are the two main groups of carbohydrates found in feedstuffs? What is each composed of? *(pages 31-32)*
3. What is the main difference between fats and carbohydrates? *(page 32)*
4. What makes proteins different from carbohydrates and fats? *(pages 34-35)*
5. Explain the difference between essential and nonessential amino acids. *(page 35)*
6. Why must nonruminants be supplied all the essential amino acids in their diet? Why is this not necessary for ruminants? *(pages 35, 37)*
7. Define high and low quality proteins. *(page 37)*
8. Evaluate the essential amino acid content of feed materials commonly used in feed diets on your farm or in your area. Use a form like the one on the next page for compiling information. *(Refer to Table 5, page 38, and to the United States-Canadian Tables of Feed Composition.)*
9. Describe the difference between crude protein and digestible protein. *(pages 39-40)*
10. What are the two main sources of water for livestock? *(page 42)*
11. Describe the difference between macro- and micro-minerals for livestock. *(page 46)*
12. What is the calcium-phosphorus ratio? *(page 50)*
13. What are the two main classifications of vitamins? *(pages 53ff)*
14. Why is it not necessary to supplement ruminants' diets with B vitamins? *(page 56)*
15. Which of the six basic food nutrients provide each of the following three basic functions? *(pages 57-58)*
    - energy
    - structure
    - regulation
16. What uses does the animal's body make of energy? *(page 58)*
17. What factors determine the amount of energy required by a given animal? *(page 61)*
18. Describe the calorie system of energy determination. *(pages 63-65)*
19. Describe the units of measure used in determining energy content of feedstuffs and energy requirements of animals. *(pages 59-63)*

## Essential Amino Acid Content of Common Feeds

(dry basis - 100% DM)

| | % Arginine | % Valine | % Methionine | % Lysine | % Tryptophan | % Histidine | % Leucine | % Isoleucine | % Phenylalanine | % Threonine |
|---|---|---|---|---|---|---|---|---|---|---|
| *Example:* Yellow corn grain | 0.48 | 0.50 | 0.19 | 0.28 | 0.09 | 0.29 | 1.37 | 0.39 | 0.54 | 0.40 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

UNIT 3

# NUTRIENT REQUIREMENTS OF LIVESTOCK

## APPLIED ACADEMIC AREAS

**Biological science**

- Compare composition of plants and animals
- Identify food nutrients that are required for proper functioning of animals'
  - body maintenance,
  - growth of young stock,
  - reproduction processes, and
  - lactation by females to support their young and for milk production
- Identify animal life cycles

**Terms to know**

fetus
flushing
gestation
gilt
ketosis
lactation
life cycle
'open' female
prepartum
stiliborn

**Mathematics**

- Employ data analysis - read and interpret graphs, tables, charts

## INTRODUCTION

This unit provides information regarding the basic nutrient requirements of livestock and the feedstuffs that can be used to meet those needs. A knowledge of livestock nutrient requirements and the composition of feedstuffs is necessary before feeds can be selected and feeding practices determined.

Each species of livestock has its own requirements for nutrients. These requirements depend upon:

- whether the animal is a ruminant or a nonruminant
- the "use" of the animal
  - production - meat, milk, wool, eggs
  - work
  - raising young
  - breeding activity
- the environment in which the animal is kept
- the age, size, and activity of the animal

As a result of studying Unit 3, you should be able to do the following:

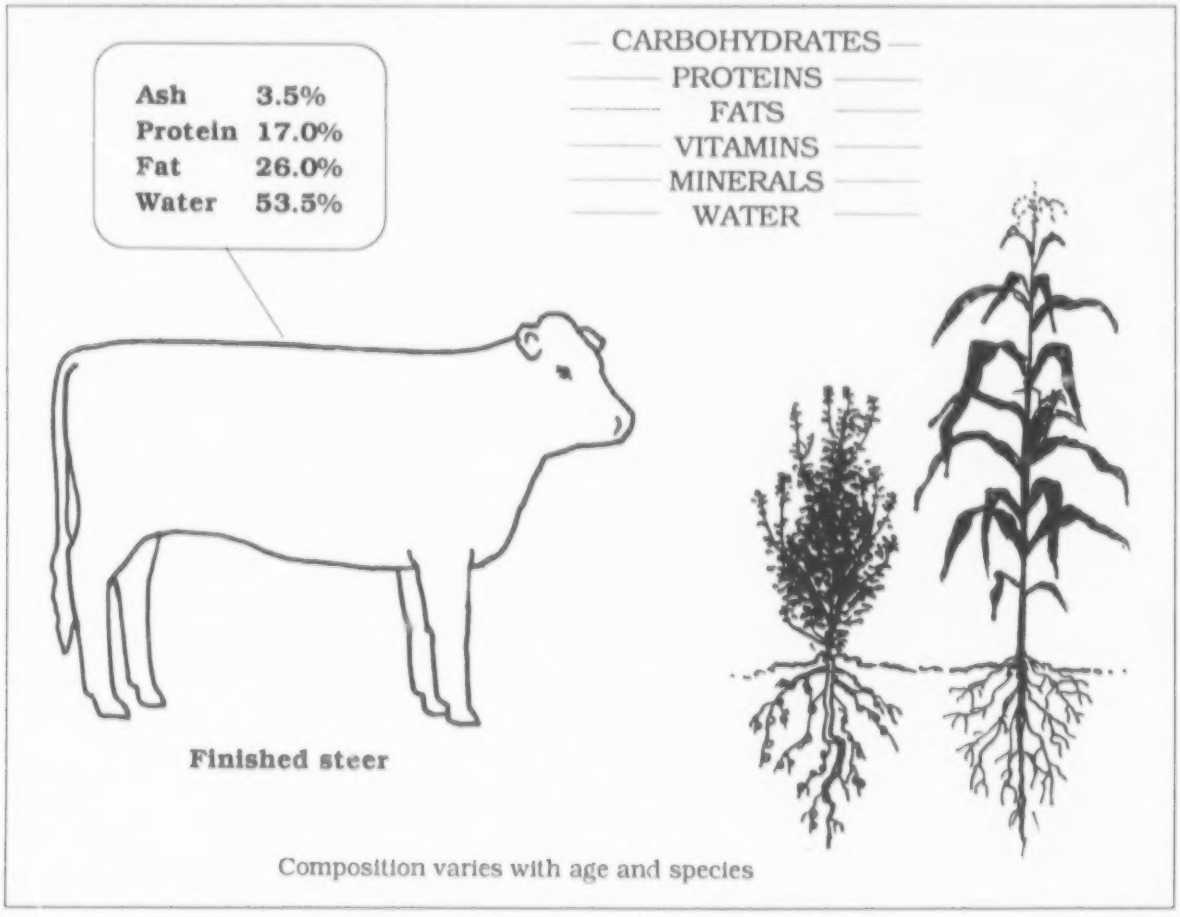
1. Compare the nutrient content of plants with the nutrient requirements of animals.
2. Explain the meaning of the terms used in determining livestock nutrient requirements: ***maintenance, growth, reproduction, lactation.***
3. Define life cycle concept of livestock feeding.

## COMPOSITION OF ANIMAL BODIES

The animal's body is composed of many nutrients similar to those produced by the process of photosynthesis in plants. Figure 54 illustrates that plants and animals contain essentially the same nutrients. However, the relative amounts and proportions of nutrients in plants and animals vary considerably. Also, the composition of plants and animals changes as each matures (Figure 55).

**Figure 54**

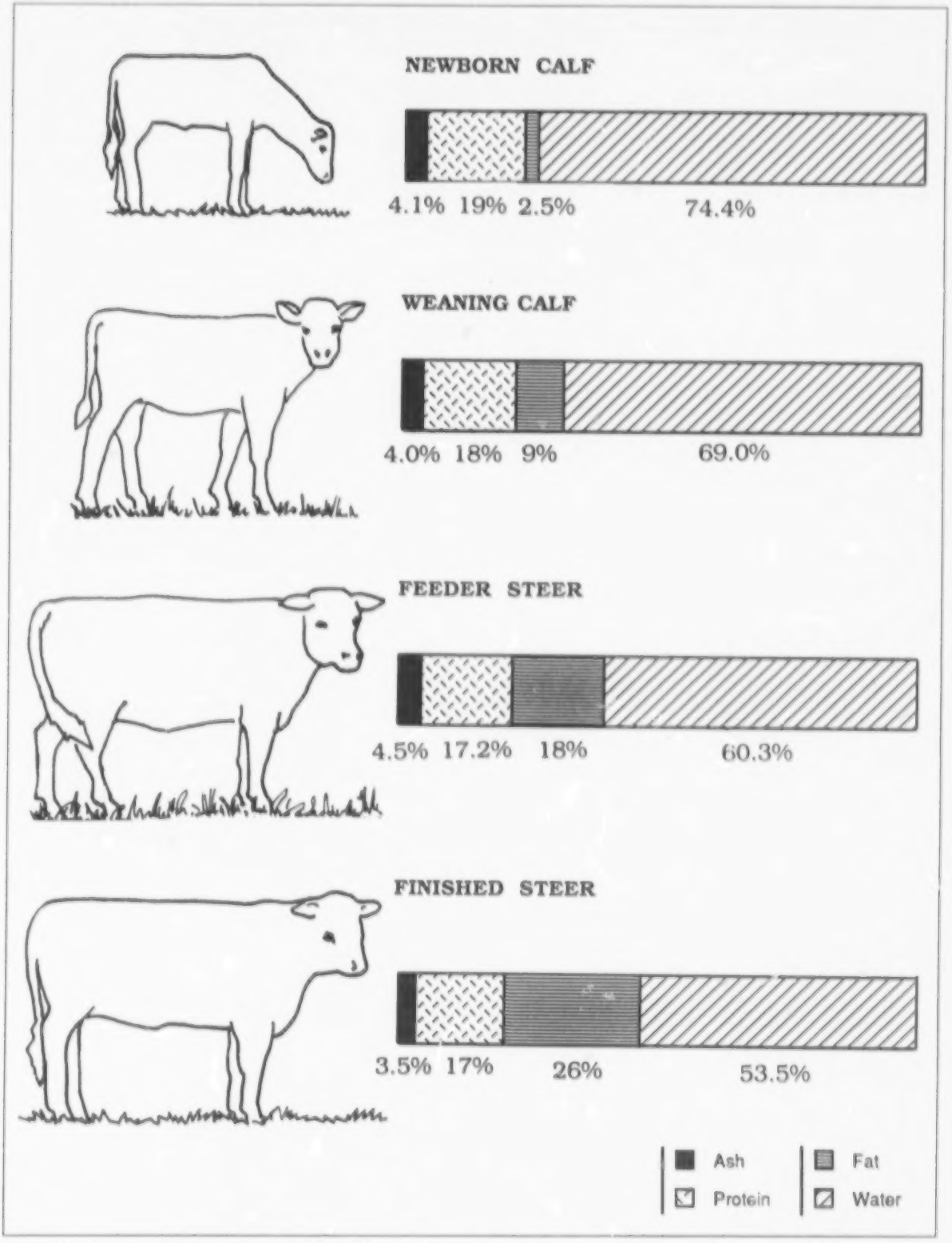
Plants and animals contain the same nutrients.




Composition varies with age and species

**Figure 55**

Animal body composition varies with age.



***Water*** - The principal part of an animal's body is water. However, the percentage of water in the body decreases as the animal matures.

***Fat*** *( Lipids)* - The percentage of fat in an animal's body increases as the animal matures. The rate of increase depends upon the purpose for which the animal is raised. Animals raised for breeding purposes should have less fat than animals raised as feeders due to the difference in diets.

***Ash*** *( Minerals)* - The percentage of ash or mineral in the animal's body remains fairly constant throughout the animal's life.

***Carbohydrates*** - Although carbohydrates are important for the animal's body to function, they make up less than 1 percent of the body composition.

***Protein*** - The percentage of protein in an animal's body remains fairly constant as the animal grows, but will decrease after the animal reaches maturity.

## THE ROLE OF NUTRIENTS IN LIFE PROCESSES

The basic nutrient requirements of livestock are calculated by nutritionists according to an animal's age, growth stage, and production. In general, these nutrient requirements are grouped according to their role in:

- ★ maintenance
- ★ growth
- ★ reproduction
- ★ lactation

### Maintenance

Part of every animal's diet is needed just to maintain bodily functions:

- ✣ heat to keep the body warm
- ✣ energy to keep the organs of the body in repair and functioning (See Figures 56 and 57.)

A maintenance diet is one which provides the proper amount of nutrients on which an animal will neither gain nor lose weight. Thus, the livestock feeder, in determining nutrient requirements, must first provide nutrients for ***maintenance***. After these have been determined, then the nutrient requirements for growth, production, gestation, and lactation can be determined.

Usually livestock require more nutrients than are supplied by a maintenance diet. However, mature male animals may be supplied only enough nutrients for maintenance when they are not being used for breeding or work. Similarly, mature female animals may be supplied only enough nutrients for maintenance when they are "open" or in the first two-thirds of the gestation period. An example is given in Figure 58 of a 1,000-pound cow, comparing the nutrients supplied in a maintenance diet with those of a late-in-pregnancy diet. The maintenance diet will not allow the animal to gain or lose weight.

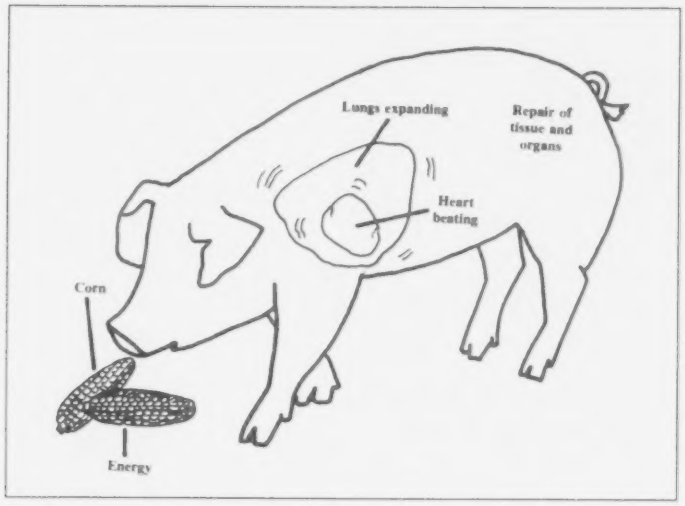



**Figure 56**

Energy is required to keep the organs of the body functioning and in repair. Corn is an excellent source of energy for all kinds of livestock.

**Figure 57**

Energy lost during metabolism is useful in keeping the animal warm. In very cold weather, animals burn energy just to keep warm.

## Growth

The growth process of livestock is mainly the production of new cells which form body tissues. Thus, the nutrient needs for growth are in addition to those required for maintenance. It is important to remember that nutrient requirements for growth are different for livestock being fed for different purposes. A beef heifer being fed for a herd replacement would have different nutrient requirements than if it were being fattened for market (Figure 59). The beef heifer kept for herd replacement would have ***less*** gain per day than one being fed for market.

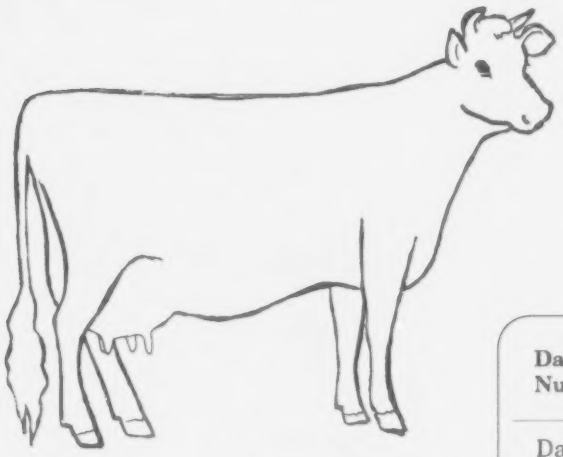


**Figure 58**

Comparison of the nutrients in a maintenance diet with those in a late-in-pregnancy diet for a 1000-pound cow.

| Daily Gain; Nutrients | Maintenance Diet | Last Third of Pregnancy Diet |
|---|---|---|
| Daily gain | 0.0 lb | 0.9 lb |
| Dry matter intake | 18.1 lb | 19.6 lb |
| Crude protein | 1.3 lb | 1.6 lb |
| Energy | 14.5 Mcal | 17.3 Mcal |
| Calcium | 15.0 g | 23.0 g |
| Phosphorus | 15.0 g | 18.0 g |

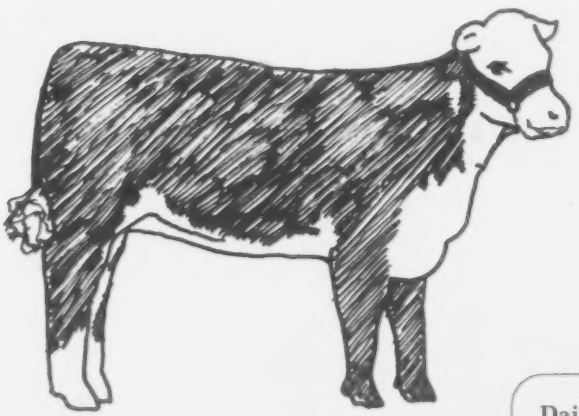


**Figure 59**

Comparison of the nutrient requirements of a beef heifer when it is fed for a herd replacement and when it is fed as a market animal.

| Daily Gain; Nutrients | Fed for Herd Replacement (last 3 months of pregnancy) | Fed for Market |
|---|---|---|
| Daily gain | 0.9 lb | 1.5 lb |
| Dry feed | 16.8 lb | 17.2 lb |
| Total protein | 1.40 lb | 1.46 lb |
| Energy | 15.2 Mcal | 19.4 Mcal |
| Calcium | 0.044 lb | 0.041 lb |
| Phosphorus | 0.033 lb | 0.033 lb |

The greatest difference in nutrient requirements is in energy fed. In addition to their protein, these nutrients are important for their carbohydrate content. As explained in Unit 2, carbohydrates and fats are the primary energy sources and are needed for finishing animals. Hence, animals fed for market require more grain and less roughage. Grain supplies less fiber and more readily available carbohydrates than roughages do.

## Reproduction

For normal fetal development, pregnant animals require nutrients in amounts above those required for maintenance. For all species of livestock, the heaviest demand for additional nutrients is during the last one-third of the gestation period. For example (Figure 60), most of the gain in weight of the developing calf occurs after the sixth month of gestation. Figures 61 and 62 show a similar fetal growth pattern for swine and sheep.

Prepartum feeding is very important for dairy cows. It helps prevent milk fever and ketosis.

**Figure 60**

Growth of the **cattle** fetus in length and weight.
Note that almost two-thirds of the growth occurs during the last one-third of the gestation period.

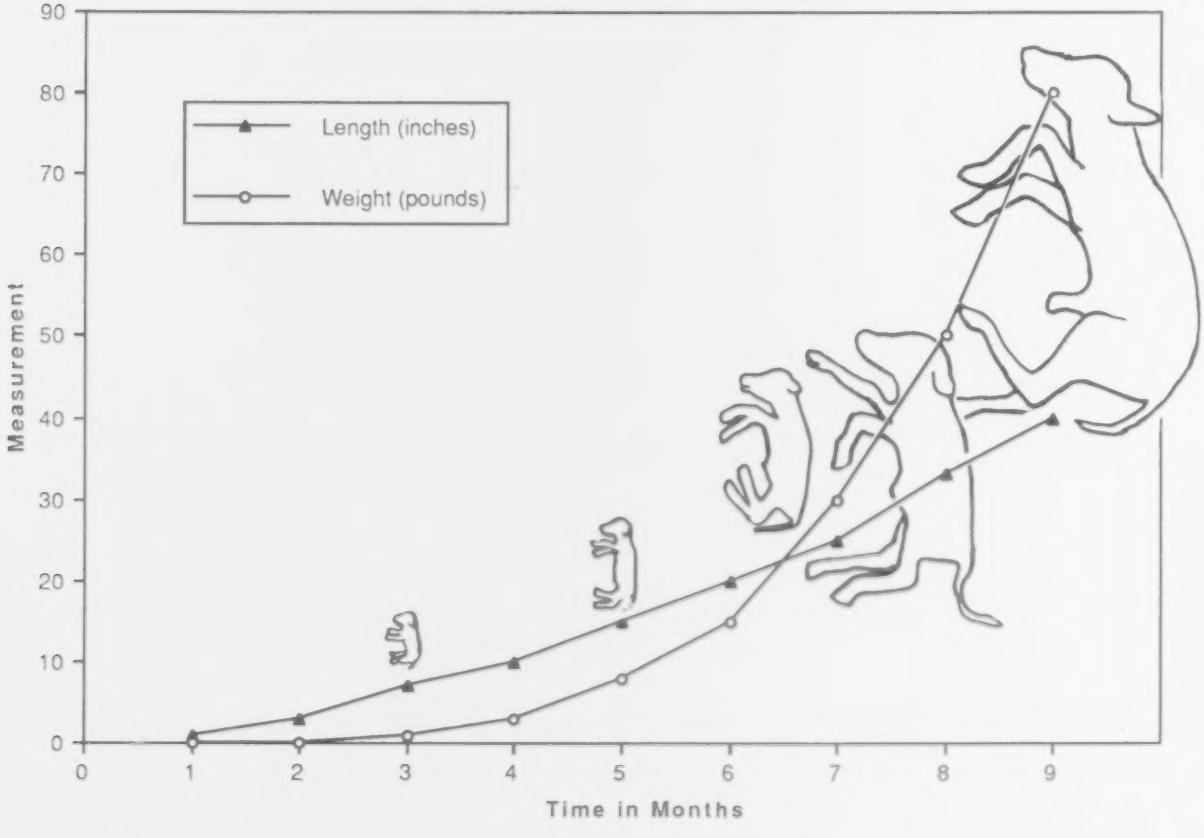


**Figure 61**

Growth of the **swine** fetus in weight.
Note that its weight increases one and a half times during the last one-third of the gestation period.

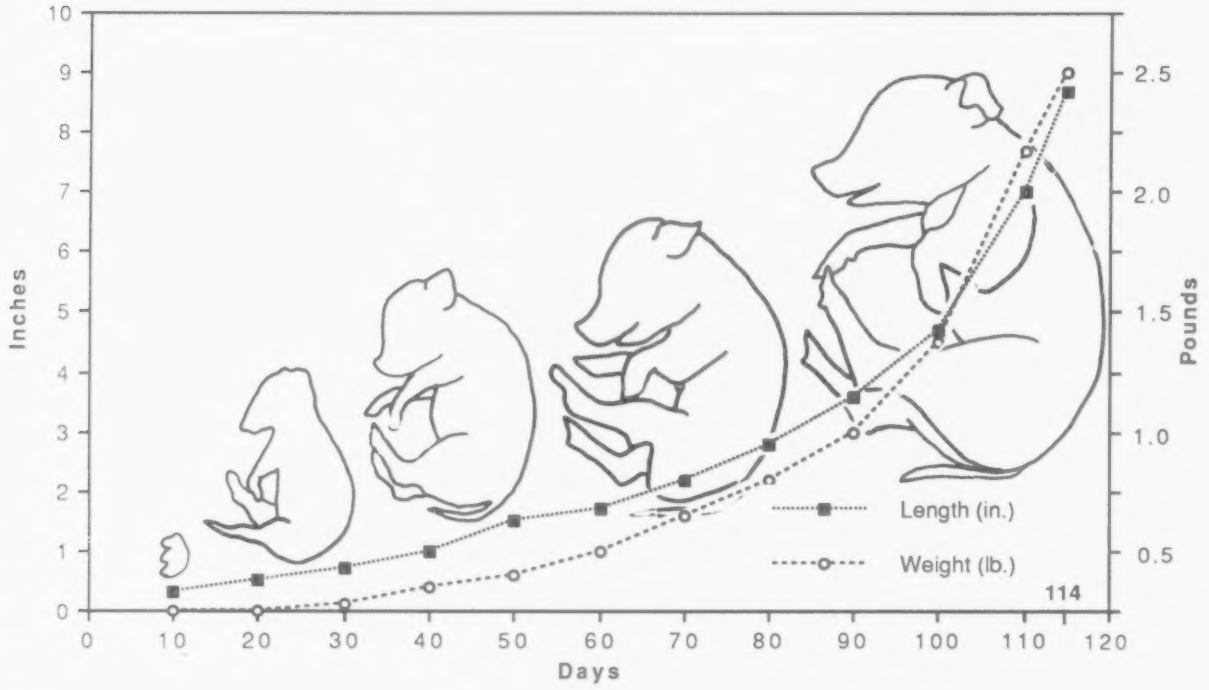
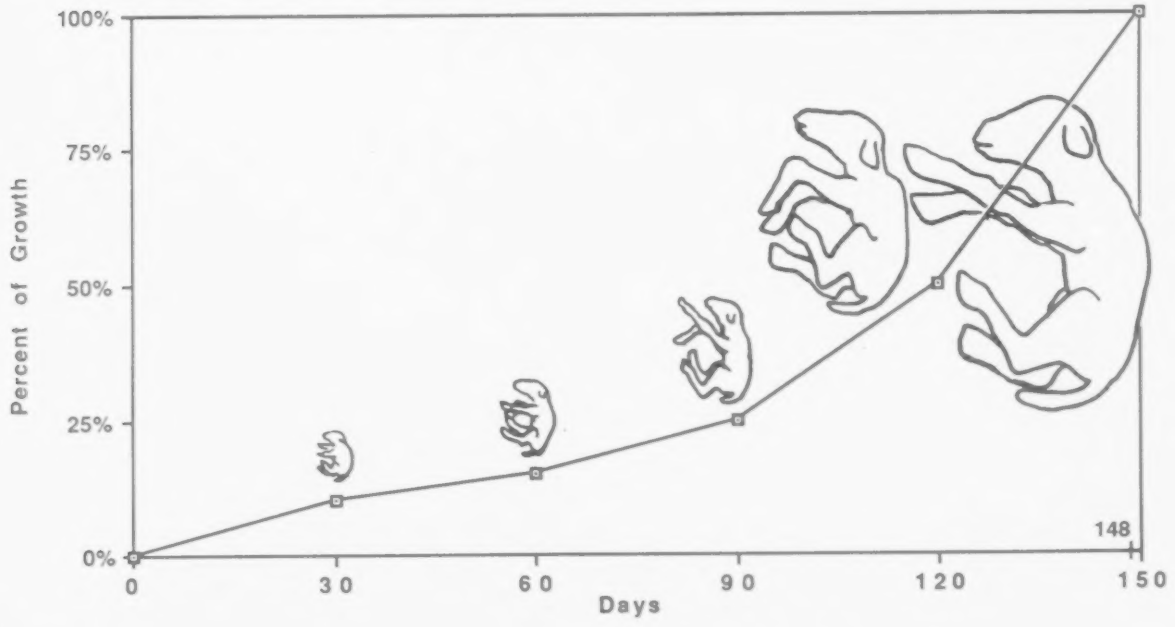



**Figure 62**

Growth of the **sheep** fetus.
Note that about 75% of the growth occurs during the last 48 days.



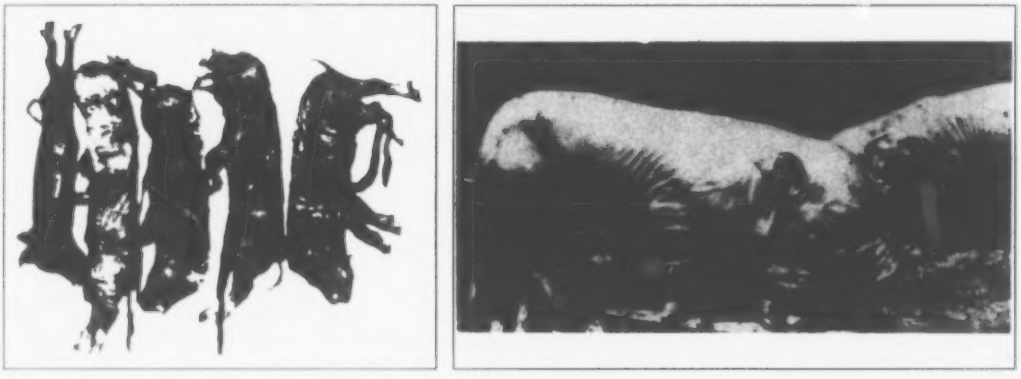
During the gestation period, nutrients must provide for the needs of the pregnant animal in the following ways:

- Maintain the body processes: tissue repair, function of organs, and heat to keep the body warm.
- Build up body reserves of nutrients against the nutrient demands of lactation.
- Provide nutrients for continued growth of immature animals, gilts, and heifers.
- Provide for normal development of the fetus.

Eighty percent of the fetus is water. Of the dry matter content, 70 percent is protein, 20 percent minerals (mainly calcium and phosphorus), and 10 percent fat. However, it is important to remember that even nutrients required in very small amounts must be supplied so that problems do not develop (like those shown in Figure 63).

**Figure 63**

Iodine deficiency. (left) A litter of hairless pigs born stillborn to a sow fed an iron-deficient diet; (right) Hairless pigs born alive.



## Lactation

During the lactation period animals need additional nutrients to support their production of milk. On a dry matter basis, milk itself contains approximately 26 percent protein, 7 percent minerals, 30 percent fat, and 31 percent carbohydrates. It is obvious, then, that high-producing dairy cows, sows nursing large litters, and ewes nursing twin lambs need nutrients much above those supplied in a maintenance diet (Figure 64).

**Figure 64**

A sow providing enough milk to properly nourish a large litter must be fed a well-balanced diet. Also, during the gestation period, the nutrients provided in her diet should be adequate for strong, healthy pigs at birth.



BEST COPY AVAILABLE

It is also possible (though rare) for one animal to require all four components of nutrient requirements: maintenance, growth, lactation, and gestation. An example is a dairy heifer that has not yet reached her full growth but is carrying a calf and is getting ready for milk production. A summary of livestock use of feed nutrients is given in Figure 65.

## LIFE CYCLE NUTRITION CONCEPT

The concept of life cycle nutrition considers the nutritional needs of livestock during each stage of its life. The two major groups of a herd or flock are ***breeding stock*** and ***immature or young stock***.

The breeding stock consists of the males and females kept for reproduction purposes. The immature group consists of the young stock that are kept for growth. Some will be selected for the breeding flock or herd; the majority will be grown and in many cases finished for meat production purposes. The immature stock must be supplied nutrients to meet their maintenance requirements and enough additional nutrients to produce the desired rate of growth.

The life cycle of the male animal is fairly simple after he has reached maturity and no longer requires nutrients for growth. The mature male must be supplied the nutrients required to maintain his body at all times. Additional nutrients are required just before and during the breeding season and when the animal is used for work.

The life cycle of the female animal is more complicated and the nutrient requirements more demanding. Each life cycle stage has special nutritional requirements, and some stages are more critical than others. Figure 66 shows the relative nutrient requirements for each life cycle stage of a ewe producing one lamb crop per year.

Figure 67 shows the life cycle requirements of a producing dairy cow. Note that during part of her life cycle the cow must be fed to provide for milk production and the development of a fetus at the same time. In early lactation, the female body will give higher priority to milk production than to body maintenance, and the animal will lose weight. Additionally, if the female is immature, her nutritional needs for growth must also be met. Throughout their lifetime all females need a part of their diet to maintain their bodies. Maintenance requirements are in addition to their other nutritional requirements.

The beef cow, sow, and mare have similar life cycle charts except for the differences in time. You may want to construct life cycle charts for your own breeding females.

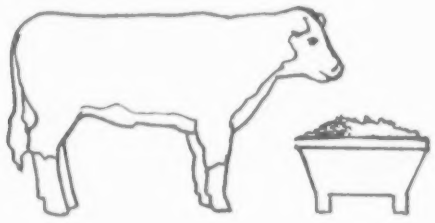
In the next chapter we will take a look at the types and composition of feedstuffs fed to livestock. Then you will find help in discovering the nutrient requirements for your particular kind of livestock. With the help of tables, you will be able to formulate diets appropriate for your situation.

**Figure 65**

Livestock use feed nutrients for various purposes.

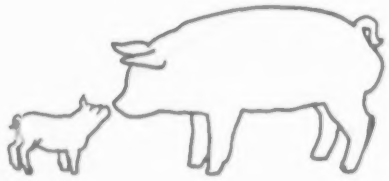
**MAINTENANCE**

**Keep body warm**
**Repair body tissue**
**Digestion, absorption, metabolism**
**Circulation of blood**
**Moving about**



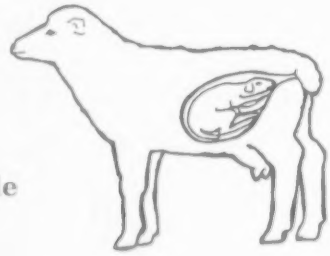
**GROWTH**

**Development of muscles, fat, bone, body tissue**



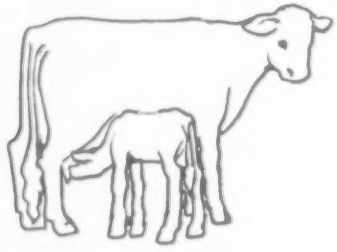
**REPRODUCTION**

**Development of fetus**
**Muscle contractions**
**Development of breeding male**



**LACTATION**

**Production of milk for young and for humans**



**WORK**

**Energy to move about and perform work**

**Figure 66**

Ewe's nutrient requirements for a life cycle including one lamb crop per year.

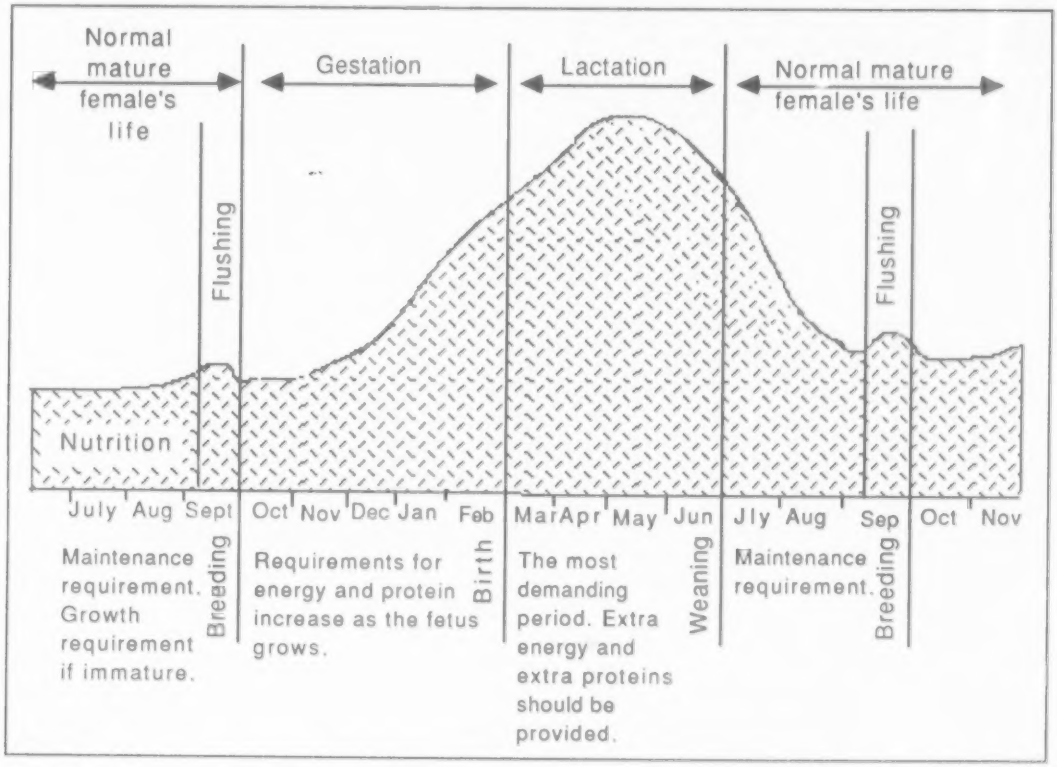
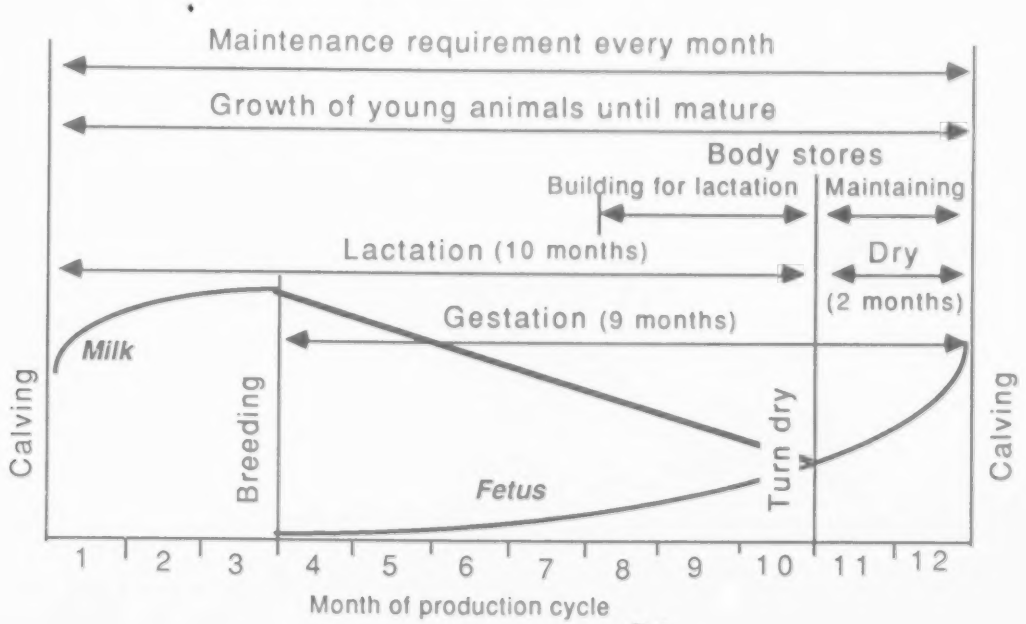

Normal mature female's life
Gestation
Lactation
Normal mature female's life
Flushing
Flushing
Nutrition
July Aug Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jly Aug Sep Oct Nov
Breeding
Birth
Weaning
Breeding
Maintenance requirement. Growth requirement if immature.
Requirements for energy and protein increase as the fetus grows.
The most demanding period. Extra energy and extra proteins should be provided.
Maintenance requirement.

**Figure 67**

Dairy cow's nutrient requirements during production cycle.



**Important biological concepts to learn from Unit 3:**

- ★ The animal's body requires the same basic food nutrients that are synthesized in plants by the process of photosynthesis.
- ★ The nutrient requirements of animals vary with the animal's age, growth stage, and production requirements.
- ★ Food nutrients must be provided to animals to maintain their bodies, for growth of young animals, to meet reproduction requirements for both females and males, for lactating females producing milk for their young and for human use, and for work.
- ★ Life cycle nutrition considers that animals have different nutritional requirements during each stage of their life.

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## REVIEW of Unit 3

After studying Unit 3, "Nutrient Requirements of Livestock," you should be able to answer and discuss the following questions.

1. Compare the food nutrient content of plants and animals. *(pages 72-74)*
2. What happens to the water, fat, and protein content of an animal's body as it matures? How do you think this might affect the composition of an animal's diet with maturity? *(pages 73-74)*
3. How do you explain the fact that though an animal's body contains very little carbohydrate, the animal requires large amounts of carbohydrate in its diet? *(page 77)*
4. How does the stage in an animal's life cycle determine its basic nutrient requirements? *(pages 74-75)*
5. What is a maintenance diet? Under what circumstances would you consider feeding such a diet? *(page 74)*
6. Why are the nutrient requirements of a growing animal different from those of a mature animal? *(page 74)*
7. How does a diet for a pregnant female differ from that of a nonpregnant female? *(pages 77-79)*
8. Describe the rate of development of the fetus during gestation. How does this affect the pregnant female's diet requirements? *(pages 77-79)*
9. What effect does lactation have on a female's diet requirements? *(pages 79-80)*
10. Does a lactating female have a maintenance requirement in her diet? *(pages 79-80)*
11. Define life cycle nutrition. *(page 80)*
12. Prepare a life cycle chart for breeding beef cows and sows. *(pages 80, 82)*

UNIT 4

# TYPES OF FEED AND THEIR COMPOSITION

## APPLIED ACADEMIC AREAS

### Biological science

- Determine nutritional value of feedstuffs by:
  - chemical analysis
  - digestion trials
- Match different kinds of feedstuffs with the nutrient requirements of different types of livestock
- Sample feeds for nutrient testing and interpret nutrient test results
- Classify feedstuffs as to their type
- Determine comparative values of different roughages
- Determine comparative values of different energy feeds
- Determine comparative values of different protein feeds
- Determine effect on their digestibility of the amount of surface area of feedstuffs that is exposed to digestive juices and to microbes in the rumen (value of grinding)
- Determine effect of heat on digestibility of starches
- Determine value of plant and animal by-products as feedstuffs
- Consider use of nonprotein nitrogen as a source of protein for ruminants
- Differentiate between organic and inorganic matter

### Mathematics

- Employ data analysis
  - Read and interpret graphs and charts
  - Read and interpret feed composition tables
- Determine relative costs of feedstuffs
- Understand percentages as a part of the whole
- Determine equivalent values
- Compare moisture content of various feedstuffs
- Read moisture tests and weigh with scales
- Convert dry matter basis feed mixtures to as-fed moisture basis

### Terms to know

abortion
additive
aleurone
annuals
antibiotic
bulk
carcass
carotene
concentrate
crimping
die
diet
ensilage
equivalent values
excerpt
extract
extrusion
fodder
forage
green chop
hammer mill
haylage
implant
inert
infestation
inorganic
jaundice
legume
limestone
mastitis
middlings
nodule
organic
perennials
pH
premix
roughage
spoilage
stover
succulent
supplement
synthetic
tankage
tetany
toxic
whey

## INTRODUCTION

Before you can select a diet, you have two important tasks to do:

- ★ Determine the nutrient requirements of the livestock to be fed.
- ★ Select the feedstuffs to be used or considered in formulating a balanced diet for the animal to be fed.

There are many different kinds of feed that can be used in formulating a balanced diet. The job of the livestock feeder is to select feeds that will provide for

- good health of the animal,
- rapid and economical growth of young animals,
- economical production of quality meat, fiber, milk, and work, and
- economy in feeding (feed conversion).

The good livestock feeder knows the nutrient value of the feeds available and knows how to use these feeds to achieve the most economical production.

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As a result of studying Unit 4, you should be able to do the following:

1. Classify feeds according to source and type.
2. Compare feeding values of different feeds of the same class (such as grains, supplements, etc.).
3. Determine the nutrient content of feeds.
4. Compare costs of feeds of the same class.
5. Select feeds as determined by their:
   a. availability
   b. suitability
   c. quality
      - time of cutting (hay and grass-legume silage)
      - moisture content
      - condition of feedstuff, such as moldy, contaminated, or having other defects that make it unsuitable for livestock
   d. digestibility and chemical composition
   e. palatability
   f. proportion that can be used in a diet
   g. relationship of one feed to another in a diet
6. Select mineral and vitamin supplements to meet the needs of livestock.
7. Select the kind and amount of preparation required for grains as determined by the kind of livestock fed.
8. Determine the legal requirements regarding the sale of commercial feeds.
9. Interpret the information on a commercial feed label.
10. Convert feeds in diets formulated on a dry matter basis (100% DM) to as-fed basis.

---

# FACTORS INFLUENCING THE VALUE OF A FEED

The value of any feed included in a diet is determined by several factors. These factors should be understood, and consideration must be given to them before a feed is selected (Figure 68). Some of the important factors are:

- ★ availability
- ★ suitability
- ★ quality, digestibility, and chemical composition
- ★ palatability
- ★ proportion of a feed that can be used in a given diet
- ★ relationship of one feed to another in a given diet

## Availability

Not all of the many different kinds of feed will be available to any one livestock feeder. Appendix Table 1C lists many different kinds of feed. But it is practical to consider only feeds that are available from home-grown sources or from the feed store. Thus, availability of feedstuffs may limit the livestock feeder in selecting feeds to formulate a diet for livestock.

## Suitability

You learned in Unit 1 that the digestive system of an animal determines to a great extent the kind of feeds it can use. You will remember that in ruminants the microorganisms in the rumen synthesize the essential amino acids and the B-complex and K vitamins. (As a safeguard, however, some livestock feeders add niacin to dairy cattle diets and thiamine to feedlot cattle diets.) Thus, ruminants, such as sheep and cattle, can use lower quality feeds more efficiently than can nonruminants, such as swine.

**Figure 68**

The selection of feeds to use in a diet is determined by several factors, such as palatability, availability, nutrient content, and economy.

## Quality, Digestibility, and Chemical Composition

Extensive research in animal nutrition has been done by conducting feed digestion trials and by chemically analyzing different feeds. (Chemical analysis of feed materials in a laboratory is shown in Figure 69.) Data from this research, given in ***averages***, are presented in Appendix Table 1C, *Composition of Selected Feeds and Their Energy Values.*

### *Quality*

The quality of a forage is determined by:

- the percentages of legume and grass and weed plants. If almost half of a hay is grass and weed plants, the quality will be much lower than that of pure legume hay.
- the content of leaves vs. stems. The higher quality hays have more leaves.
- the maturity of the crop at harvest. Even as yield increases, the quality of a forage declines with maturity (Figure 70).

**Figure 69**

Laboratory analysis is made of many feeds to determine their nutrient content. *(Photo courtesy of Janice Bowman)*

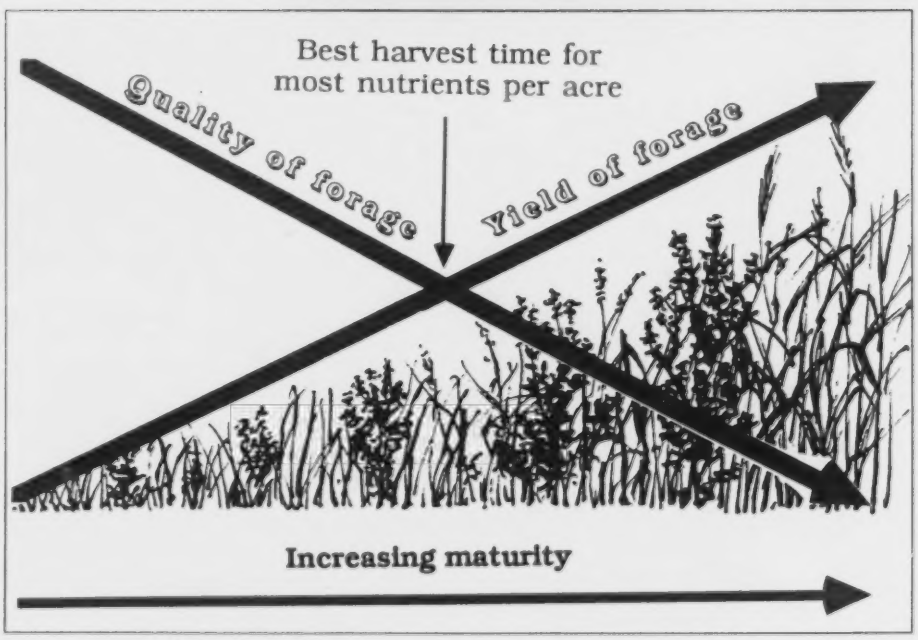


**Figure 70**

As forage matures, yield increases, but quality declines.

### *Effect of Plant Maturity on Nutrient Content*

It is a challenge to manage forages properly to obtain optimum (best) production. As Figure 71 shows, the crude protein percentage of forages declines as the plants mature. The decline is at a slower rate for legumes than for grasses. In contrast, as shown in Figure 72, the percentage of neutral detergent fiber (NDF) of all forages increases as the plants mature. This shows that the nutrient value of forages declines as the plants mature. This decline occurs regardless of how the plants are harvested — as pasture, hay, or silage.

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*Examples*

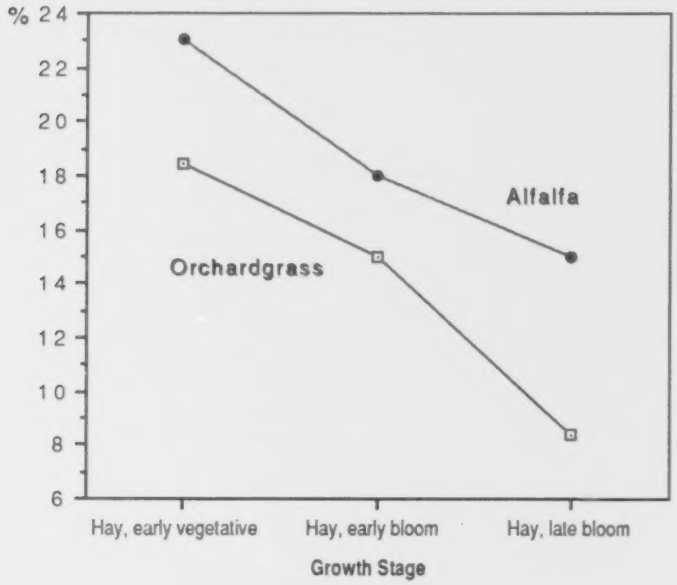


**Figure 71**

Percentage of crude protein (CP) declines as forages mature.

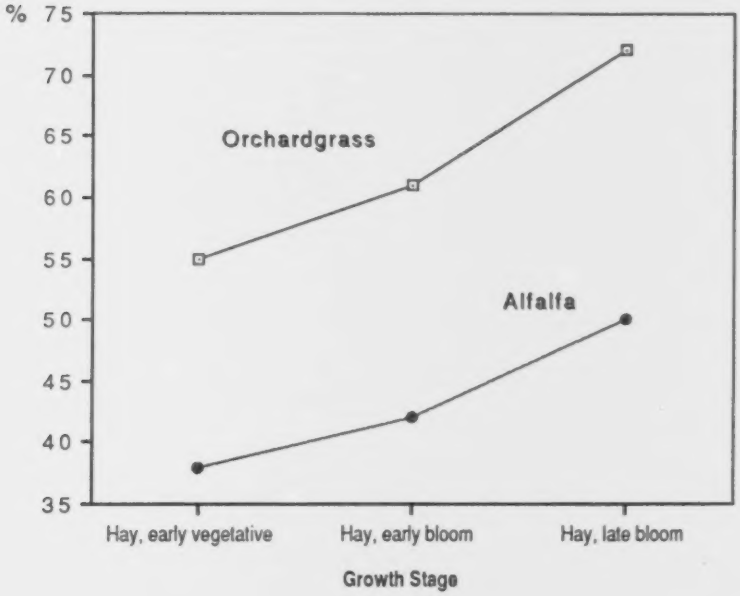


**Figure 72**

Percentage of neutral detergent fiber (NDF) increases as forages mature.

When managing the harvest of forages, it is important to balance the quantity and quality of forage produced per acre. Young plants will contain high percentages of available carbohydrates, proteins, and minerals. This will result in high quality hay, silage, or grass for grazing. Older, more mature plants will produce much higher yields per acre, but will contain more fiber and be of lower quality. Thus, harvesting should be done at the time when the crop yield is highest and before its quality declines. Rotating pastures (at different stages of maturity) is another way to make the best use of available protein and fiber for grazing cattle.

The nutrient composition of all hays, legumes, and grasses is affected by the stage of maturity when the crop is cut (Figure 73). Production is also increased when high-quality hay is fed (Figure 74).

The quality of grains is also affected by such factors as moisture content, weight per bushel, and the inert matter (trash) in the grain. Good-quality shelled corn contains about 9 percent digestible protein. In low-quality grain the digestible protein can be half that amount. Thus, adjustments in nutrient content must be made for low-quality feeds. When a large quantity of feed is available and the digestible nutrient content is in doubt, having an analysis of the feed done can be most helpful.

## Palatability

Palatability is the term used to describe whether livestock find a feed agreeable to their taste; i.e., whether they ***like*** to eat it (Figure 75). Rapid and economical weight gains of farm animals are dependent upon high feed intake. Knowing the palatability of a feed is important in selecting diets for high-producing livestock.

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**Figure 73**

Early-cut hay contains more metabolizable energy than hay cut at a later growth stage.

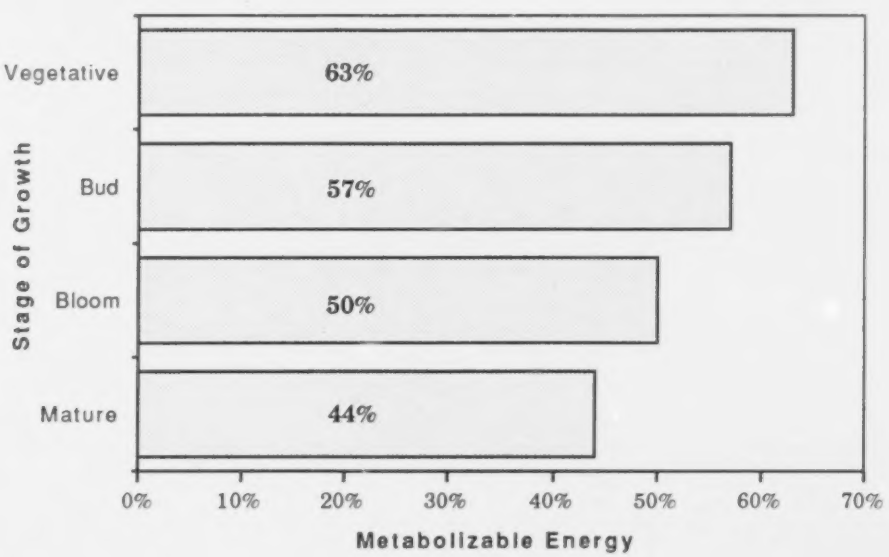
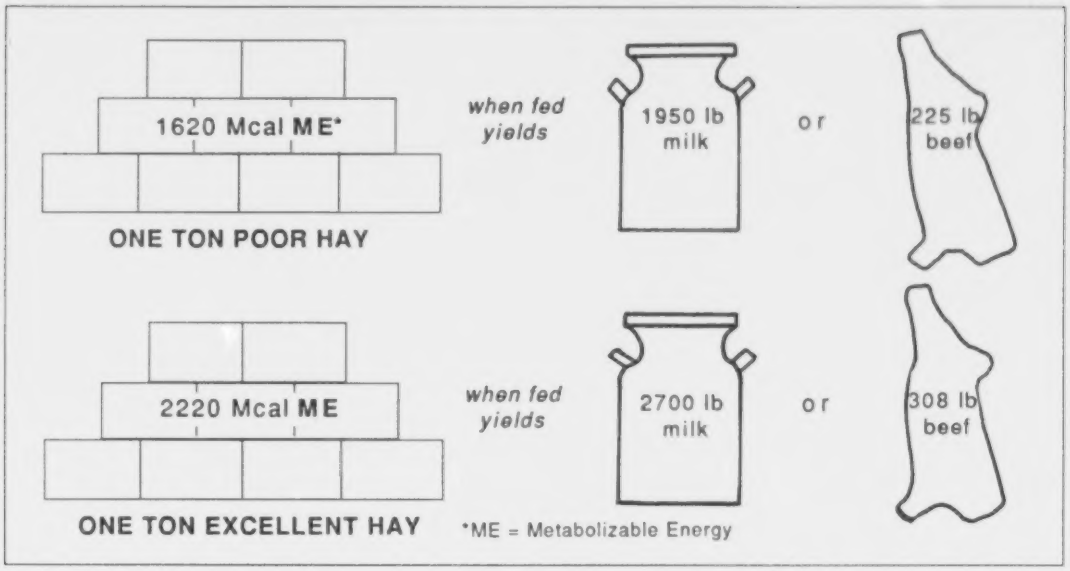


**Figure 74**

Quality hay is worth more. The production of both milk and meat is increased when high-quality hay is fed.



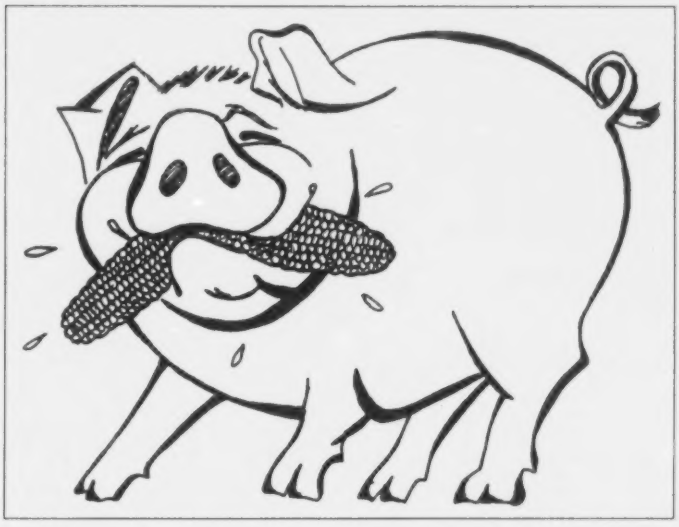



**Figure 75**

Palatability of a feed largely determines how much of it an animal will eat. Corn is very palatable to swine and other livestock.

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The palatability of feed may be affected by appearance, odor, taste, texture, and temperature. In general, when an animal has a choice of feeds, it will show a preference for one feed over another. When animals do not have a choice of feeds, palatability is of less importance. However, palatability of feed is important for high-producing animals requiring high feed consumption. When the producer wants to reduce consumption of a certain feed, he or she may add a substance of low palatability.

Texture of feed definitely affects palatability. Most livestock take readily to pelleted feeds. The particle size of ground feeds greatly influences the rate at which it is eaten. Coarsely ground concentrates and grains are consumed

Figure 76 Cattle and other livestock can pick up spores that cause disease by eating moldy feed or simply by inhaling its dust.

at a higher rate than finely ground feeds are. But coarsely ground forages for nonlactating ruminants are consumed at a slower rate and in smaller amounts.

Examples of feeds with poor palatability are weedy hay, rancid silage, and moldy grain or hay. Most moldy feeds are affected by fungi. Not only do fungi in quantity reduce palatability, but they can cause diseases like fungal abortion of cattle and aflatoxin, a nerve disorder from moldy corn. In fact, farm animals need not eat the moldy feed to have a health problem. Mold spores can easily enter the animal's lungs as it inhales (Figure 76).

## Proportion of a Feed Used in a Diet

The value of some feeds varies depending upon how much is used in a diet. For example, oats, when fed to swine, is an excellent feed in relatively small quantities. But, due to its relatively high fiber content, oats becomes less valuable if it is the main source of grain in the diet.

## Relationship of One Feed to Another in the Diet

Feed only the amounts of nutrients needed by an animal. A steer fed high-quality alfalfa hay will require less supplemental protein, minerals, and vitamins than a steer consuming corn silage as the main roughage. If protein and mineral supplements are supplied in the same amounts for the alfalfa hay-fed steer as for the one fed corn silage, feed costs will be excessive. On a DM basis, high-quality alfalfa hay (second or third cutting) may contain as much as 20-22 percent protein, 1.8 percent calcium, and 0.33 percent phosphorus. Corn silage contains about 8.1 percent protein, 0.23 percent calcium, and 0.22 percent phosphorus. Therefore, less supplemental protein and minerals (at less expense) should be fed to steers consuming alfalfa hay.

# CLASSIFICATION OF FEEDS

The following discussion of the classification of feeds will cover the feeds that are most commonly available, feed composition in general, and suggestions for use of the different feeds.

Feeds may be grouped in the following classes. (See also Table 13 and Figure 77.)

- ★ Roughages: legumes and grasses
- ★ Concentrates: energy and protein
- ★ Supplements: minerals and vitamins
- ★ Additives: hormones (usually implanted), antibiotics, and medication

To make decisions about selecting feeds, you must know about the yields and nutrient content of available feeds. You will be provided with the background information you need to formulate balanced and economical diets for your livestock using available feeds.

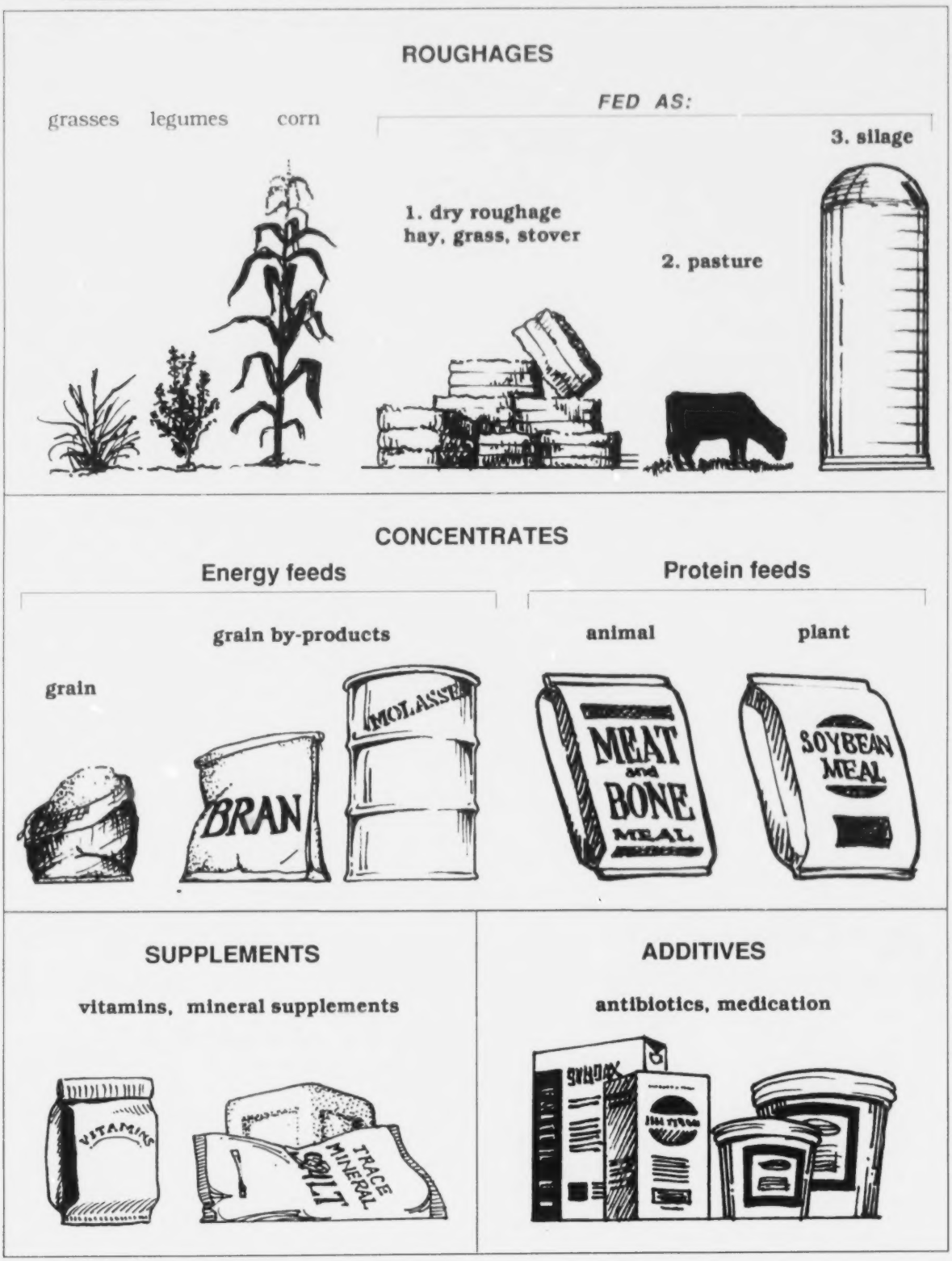
---

**Table 13**

Feed classes

| Class Number | Feedstuff | Type |
|---|---|---|
| ROUGHAGES | | |
| 1 | Dry forages and roughages | Hay, pulp, fodder, stover, straw, hulls, pods, or shells |
| 2 | Pasture, range plants, green forages | Cut and fed green, or grazed |
| 3 | Silages | Ensiled forages such as corn, grass, sorghum, legume, or mixtures |
| CONCENTRATES | | |
| 4 | Energy feeds (less than 20% crude protein) | Cereal grains, fruits, milling by-products, nuts, molasses, roots |
| 5 | Protein feeds (more than 20% crude protein) | Animal, avian (bird), marine (fish), and plant origin |
| SUPPLEMENTS | | |
| 6 | Mineral supplements | |
| 7 | Vitamin supplements | |
| ADDITIVES | | |
| 8 | Non-nutritive products | Antibiotics, hormones, flavors, coloring materials, medications |

**Figure 77** Classification of feeds



## Roughages

Roughage feeds may be grasses, legumes, or a mixture of the two fed as hay, silage, pasture, stover, or straw (Figure 77). These feed materials make up the larger part of the diet for ruminants and horses. Cows typically must be fed at least 50 percent roughage feeds, while feedlot cattle need to be supplied only about 20 percent roughages.

The significance of roughage feeds is two-fold:

- ★ Ruminant animals and horses use roughages to produce meat, milk, wool, and work. These roughages are unsuitable for human consumption.
- ★ Land unsuitable for grain crops can produce a large supply of the roughage feed for cattle, sheep, and horses.

### *Legume Hays*

Legume hays are made from alfalfa, clovers, birdsfoot trefoil, or soybeans. Legumes are plants that have the ability to use nitrogen from the air. With the aid of nitrogen-fixing bacteria in their root nodules, legumes produce nitrates for their own nutrition. Thus, their nitrogen content is higher than that of other plants. The nitrates they contain are normally converted to amino acids. So legume hays supply more protein than grass hays do. But in drought conditions the nitrates in legumes can become too concentrated and cause nitrate toxicity in the foraging livestock.

***Alfalfa*** (Figure 78)

Alfalfa is used extensively for legume hay or haylage production for the following reasons:

- ✣ It produces high yields on fertile, well-drained soil.
- ✣ It contains a high percentage of protein compared to other legumes.
- ✣ It contains fairly large amounts of calcium, phosphorus, and vitamins compared to other legumes.
- ✣ When cured properly, it is very palatable to livestock including swine and poultry.
- ✣ It is a perennial plant that is deep-rooted and drought-resistant.

However, there are some concerns with alfalfa production:

- ✣ Alfalfa weevil and potato leafhopper (insects) cause severe damage unless adequate controls are used. These control measures increase the cost of production.
- ✣ Alfalfa requires a fertile soil with a pH of 6.5 to 7 to produce high yields.
- ✣ Alfalfa requires a well-drained soil to produce well.

***Alfalfa meal, dehydrated*** is alfalfa which has been harvested during early maturity, artificially dried, and ground into meal. Characteristics of alfalfa meal are as follows:

- ✣ Alfalfa meal contains 17 percent or more crude protein.
- ✣ It is a good source of Vitamin A and calcium as well as other vitamins and minerals.
- ✣ It is often mixed with soybean meal to provide vitamins and minerals to the swine diet.

**Figure 78**

Alfalfa hay is commonly raised and cut for legume hay or haylage.

However, the cost of alfalfa meal compared to other sources of vitamins and minerals should be checked to determine the most economical source.

### *Birdsfoot trefoil*

This legume is used to some extent for hay production, usually in areas where alfalfa does not produce well. The important features of birdsfoot trefoil as a hay crop are as follows:

- Its nutritive value is comparable to that of alfalfa (Table 14).
- Like alfalfa, it is highly palatable to livestock.
- There is no problem with bloat.
- It produces better than alfalfa on poorly drained, lower pH, and less fertile soils.
- A perennial, birdsfoot trefoil produces well in the same field for many years with the use of good management practices.
- However, even on fertile, well-drained, well-managed soils, there is less feed produced by an acre of birdsfoot trefoil than an acre of alfalfa.

**Table 14** A comparison of protein and energy supplied in second cutting birdsfoot trefoil and alfalfa

| Crop | Digestible Protein | Energy |
|---|---|---|
| Birdsfoot trefoil mid-bloom | 10.7% | 0.99 Mcal/lb |
| Alfalfa mid-bloom | 12.1% | 0.97 Mcal/lb |

### *Medium red clover*

This red clover is used extensively for hay production. It is usually grown with a grass such as timothy. The important features of medium red clover are:

- It contains fairly large amounts of protein, but not equal to alfalfa.
- It is palatable to livestock.
- It yields well from the first hay cutting; the second cutting is low in yield.
- It will grow in a fairly wide range of soil conditions; its pH requirement is 6 to 6.5, less than that required for alfalfa.

Some problems with medium red clover are:

- It usually produces a good hay crop for one year only.
- The second cutting of red clover hay may cause "slobbering" in cattle and horses due to a fungus growth on the leaves.
- It usually will not yield as high as alfalfa.

### *Alsike clover*

- It has about the same nutrient content as red clover, but produces much lower yields.
- It is usually used in mixtures with red clover.
- It will grow on very poorly drained soils.

### *Ladino clover*

- It has a nutrient content equal to or above that of alfalfa.
- It has a high moisture content and so is difficult to cure; it is seldom used as hay.
- It is valuable as pasture for dairy cattle and poultry.
- When used for grazing, it should be grown with grasses to reduce the hazard of bloat.

### *Mammoth clover*

- It is a coarse, stemmy plant.
- It is not suitable for use as hay.
- It is usually used as a green manure crop, plowed under for soil improvement.

### *Sweet clover*

- The use of sweet clover for hay and pasture is declining.
- Like mammoth clover, it is usually used as a green manure crop.
- Moldy sweet clover hay can cause "sweet clover disease," which sometimes causes death from internal hemorrhage.

### *Soybean*

- It contains about the same protein, metabolizable energy, and minerals as alfalfa does.
- Soybean hay is hard to cure because of its high moisture content.
- It is used mainly as an emergency hay crop when normal sources of hay have failed. It is more likely to be ground into silage (with corn).
- Total yield in tons per acre is usually much less than for alfalfa.

## *Grass Hays*

Grass hays, as the term implies, are made from plants of the grass family (Figure 79). The plants most often used are timothy, orchardgrass, bromegrass, and tall fescue. Grass hays contain less protein and minerals than do legume hays, but have about the same levels of metabolizable energy.

**Figure 79**

Sheep grazing in a grass pasture

### *Timothy*

- Timothy makes a very palatable hay if cut early; for best quality – as the heads emerge.
- It has a shallow root system and so is not drought-resistant.
- It is usually grown in mixture with red clover or alfalfa.

### *Orchardgrass*

- Early-cut orchardgrass, as the heads emerge, provides good feed for cattle, sheep, and horses.
- It is drought-resistant, compared to timothy.
- It makes early spring growth, so is often used for early spring pasture, and also produces forage during the hot, dry summer months.

### *Bromegrass*

- Bromegrass is a palatable grass to both cattle and sheep when cut early.
- It is usually used in mixtures with alfalfa.
- It is more drought-resistant than timothy.

### *Tall fescue*

- Tall fescue is a coarse-stemmed grass with heavy leaf blades.
- It does not make as palatable a hay for cattle, sheep, and horses as the previous grasses.
- But when cut early, it makes good hay for cattle and sheep on maintenance diets. Its nutritional content is as good as that of other cool-season grasses.
- Tall fescue is sometimes used as winter pasture for beef cows.
- It can be used as a ground cover (erosion control) in areas trampled by livestock.

***Fescue toxicity*** *

However, a serious problem that affects 90 percent of tall fescue plantings is the presence inside the grass of a fungus (an endophyte) which causes fescue toxicity in grazing animals. Symptoms of this poisoning observed in dairy cattle, beef cattle, and sheep are:

- lower feed intake
- lower weight gains
- lower milk production
- higher respiration rates
- higher body temperatures
- rough hair coats
- more time spent in water and in the shade
- less time spent in grazing
- excessive salivation
- reduced reproductive performance

The economic losses due to these problems have been estimated at $500 million annually in beef production alone.

When methods to combat fescue toxicity are being considered, two characteristics of the endophyte are very important to keep in mind:

1 ) There is no outward sign in a fescue planting that the fungus is present. A lab analysis is needed to show its presence.
2 ) The fungus is transmitted through the seed only, not in any other way.

The best way to insure that a stand of fescue is entirely free of the endophyte is to use chemicals (following label instructions carefully) to eradicate the infected grass. Following this, replanting with endophyte-free seed may seem a drastic, expensive practice. But the returns can be increased by at least $75.00 per acre at current beef prices ***for every year*** of the life of the stand. Other methods of management, such as crop rotation, dilution with other crops, and careful seedbed preparation, may improve the situation of endophyte-infested fescue, but will not eliminate it.

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* Ball, D.M.; Lacefield, G.; and Hoveland, C.S. *The Fescue Endophyte Story*, Oregon Tall Fescue Commission, Salem, Oregon

### *Straws and stover*

Oat and wheat straw are maintenance feeds. They should be used only for body weight maintenance, not for production purposes.

- Straw is more valuable as a bedding than as a feed.
- Corn stover (corn stalks minus ears), like straw, should be used as a maintenance feed.
- Whenever straw or stover is the main roughage by necessity, the concentrate feeds should have a high level of proteins, minerals, and vitamins.

## *Silage*

Silage can provide the main source of roughage for sheep and beef and dairy cattle. Good silage is obtained from plants such as corn, legumes, grasses, or legume-grass mixtures. When stored in an air-tight storage structure, fermentation occurs, preserving the forage and making it more palatable. Many dairy and beef cattle farms have equipment for silage such as that shown in Figure 80.

### *Corn silage*

- Due to the large amount of plant material that can be harvested per acre from a corn field, corn silage will out-yield in metabolizable energy any other plant grown.

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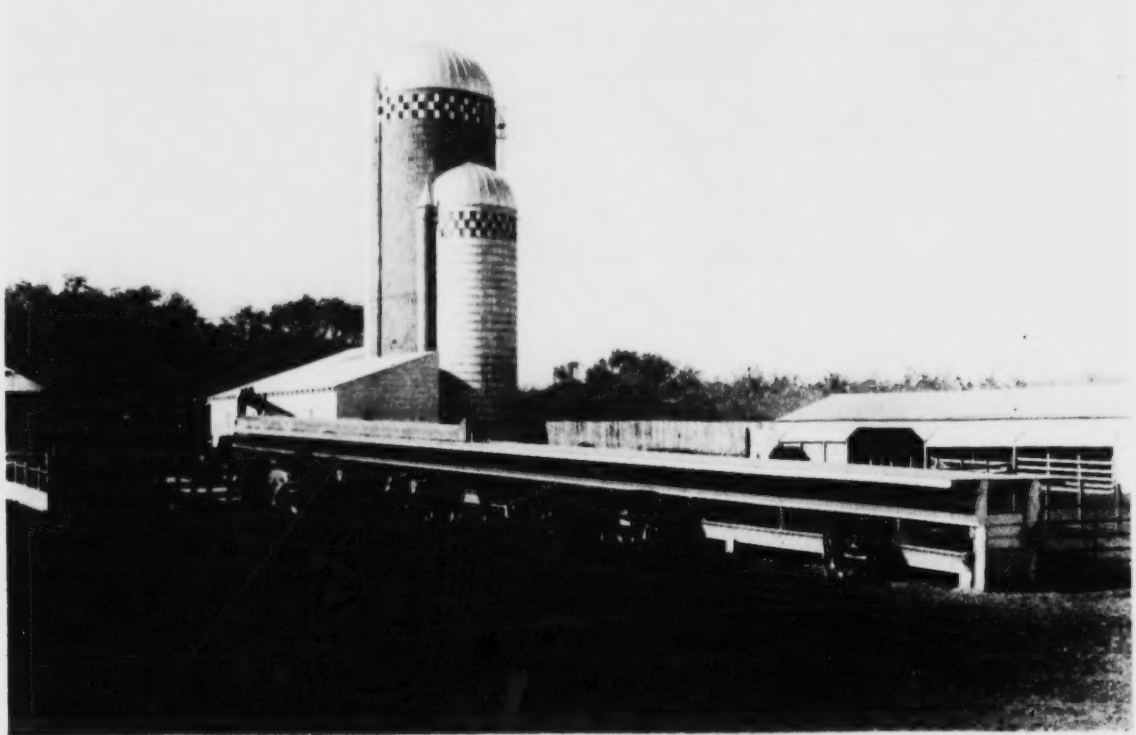
**Figure 80**

Equipment for storing and feeding silage on the farm should be labor-saving and economical. *(Jamesway Division, Butler Manufacturing Co.)*



- Corn silage is a high energy feed, but is low in protein and minerals.
- Urea is often added to corn at the time of ensiling in order to increase the protein content of the silage when consumed by ruminants.
- Mineral sources such as limestone and bone meal, which supply calcium and phosphorus, are also sometimes added to corn silage.

### *Grass-legume silage*

- The total amount of plant material produced per acre is higher from a grass-legume mixture than from a grass or legume alone.
- Nutrients produced are equal to those of a grass-legume hay when converted to a dry basis.
- It will contain more protein and minerals than corn silage does, but a lower amount of metabolizable energy per pound of material.
- The addition of corn to grass-legume mixtures (when they are wet) at the time of ensiling increases the amount of metabolizable energy.

## *Pastures*

During the growing season, pastures can be the main source of feed for cattle, sheep, and horses. Even in late fall, a portion of these animals' forage needs can be met by grazing in pastures (Figure 81). Also, if the crop is a legume such as alfalfa or ladino clover, pastures can be an excellent source of feed for swine (though such use is decreasing rapidly).

### *Grass pastures*

- Kentucky bluegrass is the most widely used plant for permanent pasture production.
- When properly managed, bluegrass pasture can serve as the only source of feed for maintaining cattle, sheep, and horses.
- Other grasses often used for pasture are bromegrass, timothy, orchardgrass, and sudan grass. (Sudan grass, however, is not recommended for horses.)

**Figure 81**

Cattle grazing in a grass pasture in late fall.

- All these grasses (including Kentucky bluegrass) are perennials except sudan grass. As an annual, sudan grass must be seeded each year.

### *Legume pastures*

- Legumes have the ability to use nitrogen, a building block of protein, from the air.
- Legume pastures are usually higher in protein and total nutrients than grass pastures are.
- Legumes used as pasture crops are alfalfa, ladino clover, white clover, red clover, lespedeza, and alsike clover.

### *Legume-grass mixture pastures*

Legume-grass mixtures are usually more satisfactory as pasture for cattle and sheep than legumes alone for the following reasons:

- There is less danger of bloat to cattle.
- There is a greater total yield of material, hence a greater carrying capacity.
- There is a longer grazing season.

### *Emergency pastures*

Emergency pastures are used as a food supply when permanent grass or legume-grass mixtures are not available. Crops often used as emergency pastures are rye, sudan grass, and sudan grass-sorghum crosses. Rape or canola, corn, and wheat are also used, but rarely.

***Rye*** sown in early fall, between September 1 and 15, will usually supply a late fall pasture. Rye will also grow early in the spring, providing an early spring pasture. In the late spring, rye plants become less palatable as the seed heads (spikes) start to form.

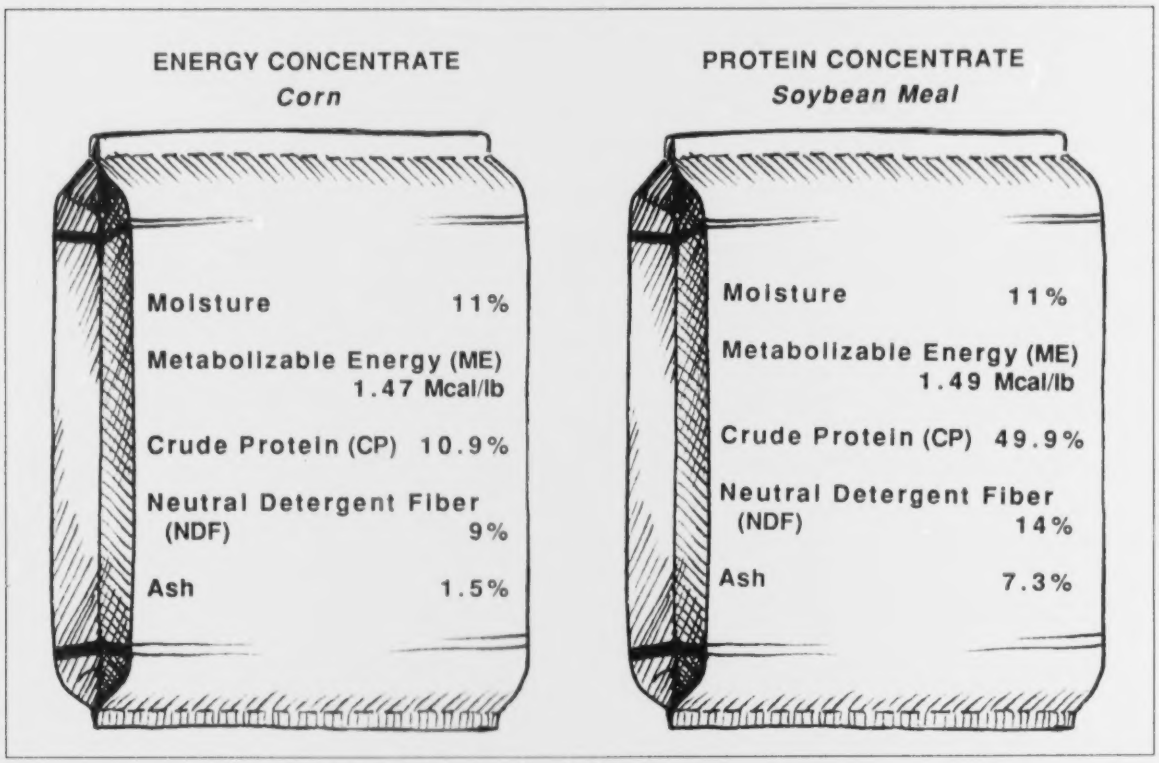
***Sudan grass*** and ***sudan-sorghum crosses*** produce a large quantity of forage during the summer and early fall. Young plants that are 18 to 24 inches tall may contain prussic acid, which is poisonous to livestock. Thus, pasturing or use as green chop should be delayed until plants are older. The plants become less palatable as the seed heads start to develop.

## Concentrates

Concentrate feeds consist of grains, grain by-products, and protein feeds of both plant and animal origin. (Refer back to Figure 77.) They are divided into two classes: energy concentrates and protein concentrates (Figure 82).

Figure 82

Comparison of energy concentrates and protein concentrates




## *Energy Concentrates*

### GRAINS

Most of the concentrate feeds fed to livestock are grains. Grains usually provide the most economical source of energy and have the most value in finishing livestock. Grains are highly digestible and palatable. However, they usually do not supply enough protein, vitamins, and minerals to meet all the nutrient requirements of livestock.

As with roughages, grains can be a farm-produced source of feed. They should be used in livestock diets to keep costs low. Only enough purchased feeds should be used to supply the nutrients not supplied by home-grown grains and roughages. For highly specialized livestock feeders, all the feed materials may be purchased. To keep feed costs lower, there should be only enough protein, mineral, and vitamin feeds purchased to balance the diet.

#### The Most Common Feed Grains

These are the grains used extensively as livestock feed: corn, oats, barley, wheat, grain sorghum (milo), and rye.

***Yellow corn*** is one of the most widely used feed grains for all types of farm animals.

- Corn is high in metabolizable energy, so it is excellent for finishing livestock.
- Yellow corn contains some carotene, a source of Vitamin A. But the Vitamin A content deteriorates during storage.
- Corn is very palatable to all livestock species.
- Corn is low in protein and minerals, especially calcium. Thus, protein and mineral supplements usually must be added.
- Corn and cob meal (ground ear corn) can be used for cattle and sheep, and also for swine when extra bulk is desired. Corn meal, because it contains ground cob, contains less energy than shelled corn. Therefore, more corn meal must be fed to equal the amount of energy provided in shelled corn.

***Oats***, next to corn, is the grain most widely fed to livestock. The amount of oats used in the grain part of a livestock diet is usually much less than the amount of corn.

- When the cost of particular nutrients is considered, oats is usually more expensive than corn.
- Oats supplies 12 percent crude protein, whereas shelled corn supplies 9 percent.
- With its fibrous hulls, oats supplies more bulk than shelled corn does.
- Oats is often used as the only grain for horses.
- It is a good creep feed for cattle and sheep.
- For swine, the feeding value of oats is from 70 to 85 percent of the value of shelled corn, depending upon the amount of hull present.
- Oats is quite frequently used in feeding sows and gilts during the gestation period when less energy is needed.
- Oats generally should not make up more than 25 percent of the replacement for corn in the grain diet for swine.

***Barley*** is a good substitute for corn and can be fed to all species of livestock. Cost comparisons should be made to determine the economic value of feeding barley instead of another feedstuff.

- Like corn and oats, barley is an energy-supplying grain.
- Barley has less metabolizable energy, but more protein than corn.
- Because of its hard seed coat, barley should be processed (ground or rolled) for livestock.
- Barley is a better grain than oats for finishing livestock, as barley contains more metabolizable energy.
- For swine, barley can replace part or all of the corn in diets. Sometimes a disease called "scab of barley" infects barley, causing it to be unpalatable to swine. The disease may even have poisonous effects if swine are forced to eat the contaminated feed.
- Barley is widely used for cattle in the upper plains states. About 60 percent of the grain diet of cattle can be made up of barley, but no more, or they may not eat the feed as readily. Barley is not as palatable as corn is to cattle.

***Wheat*** is a widely grown grain in the Midwest. Because of its value as human food, however, it is generally too expensive to feed to livestock. Wheat is usually grown as a cash crop rather than as a feed crop.

- Wheat has a feeding value slightly higher than that of corn. It contains slightly more protein than corn does. The metabolizable energy (ME) content is equal to that of corn.
- Wheat should be coarsely ground when fed to livestock. Finely ground wheat forms a sticky mass in the mouth when eaten. It also results in a dusty concentrate mixture.
- Wheat is usually limited to less than 50 percent of the concentrate diet for both cattle and swine.

***Grain sorghum (milo)*** is the most common grain fed to livestock in certain areas of the Midwest and West.

- The nutrient value of grain sorghum is roughly equal to that of corn.
- Grain sorghum is highly palatable to all classes of livestock.
- If the price compares favorably to corn, grain sorghum can serve as the only grain in the diet.
- The amount of protein in grain sorghum varies from 7 to 11 percent, depending upon the hybrid or variety. Therefore, when a certain grain sorghum is used in a balanced diet, the protein percentage it contains should be known.
- Sorghum grain is very hard and should be ground for full digestion by livestock.

***Rye*** is probably the least used in livestock concentrate diets, of the six feed grains described in this unit.

- Rye is not a very palatable feed.
- It is frequently contaminated with ergot, a fungus disease. Ergot can cause pregnant animals to lose their young (abort) before birth time.
- In food nutrient value, rye is about equal to barley.
- Rye should not make up more than 20 to 25 percent of the concentrate diet for cattle and swine.
- Rye grains are small and hard and should be ground for full digestion.

***Summary of the Six Feed Grains*** - Corn is by far the major energy source as a feed grain for livestock in the Midwest. Corn is palatable, it is an economical source of energy, and it is well adapted to production in the Midwest. Compared to corn, grain sorghum is less readily available; wheat is less economical; and barley, rye, and oats are lower in energy. Barley and rye are also somewhat less palatable and are not always available.

## Value and Costs of Feed Grain Sources

Table 15 gives the relative values of the six grains in diets when substituted for corn. The metabolizable energy (ME) and total protein content of the grains are given for comparison purposes. Limitations in use for each grain in comparison with corn are given under *Remarks*. The amount

of energy per unit of grain is not the most important factor in livestock nutrition. It is the cost of energy per unit of gain or other production factor that is more important. Therefore, the most economical energy source available should be used. The relative feeding values in Table 15 can be used to make this calculation.

### *Calculating Costs of Corn Substitutes*

To calculate the relative dollar value of a corn substitute (such as grain sorghum) for swine, use the following procedure. ➡

**Table 15** Relative values of grains when substituted for corn in the diet *(corn = 100%).* Moisture content as-fed.

| Grain wt/bu | Metabolizable Energy - ME kcal/lb | Total Protein TP % | Relative Feeding Value % | Remarks |
|---|---|---|---|---|
| CORN -yellow 56 lb | 3.03 | 9.6 | Swine 100<br>Cattle 100<br>Sheep 100<br>Horse 100 | High energy<br>Very palatable<br>Source of Vitamin A<br>Low fiber |
| OATS 32 lb | 2.65 | 11.8 | Swine 80<br>Cattle 70-90<br>Sheep 80<br>Horse 85-90 | Low energy<br>Palatable<br>High fiber; limited in swine diet |
| BARLEY 48 lb | 2.90 | 11.9 | Swine 90<br>Cattle 90<br>Sheep 90<br>Horse 95 | High fiber<br>Lower energy<br>Palatable |
| WHEAT 60 lb | 3.08 | 14.2 | Swine 100-106<br>Cattle 100-105<br>Sheep 90- 95<br>Horse 100 | Limit to 50% of diet<br>Palatable<br>Usually too costly |
| GRAIN SORGHUM (Milo) 56 lb | 3.03 | 11.1 | Swine 95<br>Cattle 90<br>Sheep 100<br>Horse 95 | Palatable<br>Low fiber<br>Some bird-resistant milos have hard coat, so value reduced 80-90% the value of corn |
| RYE 56 lb | 2.88 | 12.1 | Swine 90<br>Cattle 100<br>Sheep 80<br>Horse 100 | Low palatability<br>Possible ergot toxicity<br>Next to wheat in protein content<br>Laxative when fed in high amounts |

***Example:*** *grain sorghum*

1 ) Determine the price of corn per pound.

If corn is $2.72 per bushel, a pound of corn (56 pounds per bushel of shelled corn) will be worth $0.0486 per pound.

(2.72 ÷ 56 = 0.0486)

0.0486 x 100 = 4.86

One hundred pounds (100 lb) of corn has a value of $4.86.

2 ) Assume that grain sorghum is worth 95% of the value of corn for swine (from Table 15). 100 pounds of grain sorghum would be worth $4.62.

(4.86 x 0.95 = 4.617 or $4.62)

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## Processing Grains

### PURPOSES

Livestock nutritionists generally agree that grain feed processing has three purposes:

- to increase digestibility,
- to increase palatability, and
- to reduce labor and storage costs.

The end result of grain processing should be improved feed efficiency and rate of animal gain. Since feed processing can be costly, it is important that the value of improved efficiency and performance is significantly greater than the costs of processing. The type of diet being fed influences the value of processing. For example, milo has a hard coat; its feeding value is improved more by grinding than corn would be. The amount of roughage in a ruminant's diet also influences the value of grain processing. Beef cattle fed very high concentrate diets did not benefit when corn in the diet was crimped. But when high amounts of roughage were fed, crimping the corn did improve performance.

When considering the purchase of feed processing equipment, make certain that the feeding trials you study in making your decision match the feeding program you will be following.

### METHODS

There are a number of grain processing methods available. In this manual, the following will be considered:

- Grinding
- Pelleting
- Steam rolling, cooking, and flaking

#### *Grinding*

Grinding is done by passing the grain through a hammer mill. The fineness of grinding can be varied greatly. The results of animal feeding trials (experiments) can vary due to the difference in fineness of grinding. There are several factors to consider when grinding grain as a method of feed preparation.

Finely ground grain may reduce the palatability or rate of consumption. There may also be more waste through blowing and spillage. But finely ground grain can be digested more easily because more surface area of each kernel is exposed to digestive juices. (See Table 16.) The loss in feed intake from lower palatability and possible digestive disturbances may offset the increase in percentage of nutrients digested.

Grinding grain for use in complete-feed mixes prevents sorting of individual ingredients both by the animals and during transportation of the feed. It also results in more uniform mixing with other ingredients.

Fine grinding is desirable for grain sorghum when fed to cattle. Also, for swine, the feeding value of oats is increased 30 percent and barley 24 percent by grinding. However, grinding grain usually does not improve digestibility for animals like sheep that thoroughly chew their food.

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**Table 16**

Percent nutrient digestibility of corn from fine and coarse grinding

| Nutrient | Coarse Grind % | Fine Grind % |
|---|---|---|
| Dry matter | 64 | 70 |
| Protein | 79 | 83 |
| Fat | 69 | 75 |
| Nitrogen-free extract | 74 | 79 |

*Source: Cornell University, Ithaca, NY*

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***Pelleting*** (Figure 83)

Feed that is to be pelleted is first finely ground and steamed. The wet feed is then forced through small round openings in a machine die. As the spaghetti-like strands emerge, they are cut into pellet-size pieces.

There are definite advantages to pelleting feed in both digestibility and physical handling.

- Energy digestibility can be improved because the heating process changes the starch molecules, partially cooking them and making them more digestible. Fiber digestibility is also improved.
- Feed intake is usually increased.
- The feed is more compact, so less storage space is required.
- Less feed is wasted during feeding.
- Pelleting reduces the dustiness of feed, so the environment is healthier for both animals and workers.
- Pelleting prevents sorting of ingredients by the animal, so helps guarantee better nutrition.

The one disadvantage of pelleting is that its increased cost may offset the advantages.

**Figure 83**

Pelleting of feeds has many advantages.

*Research Results*

A research study, conducted by the Animal Science Department of The Ohio State University, dealt with pelleted and meal (ground and not pelleted) feeding of swine. These animals were fed a corn and soybean meal diet containing 18 percent crude protein. Results of this study are given in Table 17. These data show that:

- Pigs fed the pelleted feed gained 0.06 lb more per head per day than pigs fed the meal diet.
- Pigs fed the pelleted feed consumed 0.16 lb less feed per day than pigs fed the meal diet.
- Feed conversion shows that pigs on the pelleted diet needed 311 lb of feed per 100 lb of weight gain, while pigs on the meal diet needed 332 lb of feed per 100 lb of weight gain.

**Table 17**

Comparison of weight gain and feed cost when pelleted and meal diets were fed to swine.

| Item | Meal | Pellets |
|---|---|---|
| Number of pigs | 72.00 | 71.00 |
| Initial weight of pigs (lb) | 57.00 | 56.00 |
| Final weight (lb) | 202.00 | 207.00 |
| Daily gain (lb) | 1.63 | 1.69 |
| Daily feed intake (lb) | 5.42 | 5.26 |
| Feed per pound of gain (lb) | 3.32 | 3.11 |
| Feed cost per pig ($) | $ 31.57 | 31.19 |
| ***Growing Period*** | | |
| Feed per pound of gain (lb) | 2.60 | 2.49 |
| Feed cost per pig ($) | $ 9.49 | 9.50 |
| ***Finishing Period*** | | |
| Feed per pound of gain (lb) | 3.88 | 3.63 |
| Feed cost per pig ($) | $ 22.08 | 21.60 |

- During the growing period the feed cost per pig for pelleted and meal feeds was almost the same.
- During the finishing period there was a slight advantage in favor of the pelleted feed in less feed required and lower cost.

Research done at The Ohio State University on feeding lambs showed the following: completely pelleted diets, self-fed, require 39 pounds less feed per animal than the same diet hand-fed and not pelleted. (Results are given in Table 18.)

**Table 18**

Amount of feed required for 26 pounds of gain in lambs– hand-fed and not pelleted as compared to self-fed and pelleted

| Feed Diet | Hand-fed (not pelleted) | Self-fed (pelleted) |
|---|---|---|
| 50% alfalfa hay (13% protein) | 109.5 lb | 90.0 lb |
| 40% ground shelled corn | 87.7 lb | 72.0 lb |
| 10% soybean meal | 21.9 lb | 18.0 lb |
| **Total** | 219.1 lb | 180.0 lb |

*Data from Cooperative Extension Service, The Ohio State University*

### *Steam Rolling, Cooking, and Flaking*

Steam rolling, cooking, and flaking are processing methods that have been used on various grains. Their primary purpose is to increase the digestibility of starch in the grain. Treatment with heat and moisture makes starch more readily digestible.

Sorghum, for example, has very low starch digestibility. Steam flaking was successfully used on sorghum at Texas A & M University to raise its digestibility level almost to that of corn. Steam rolling of barley has also been done, with results that indicate that it may be profitable.

Research done at Colorado State University on finishing beef cattle reveals that using the cooking-flaking process on cattle feed causes more efficient use of grain. The study also found that to make practical and economical use of steam rolling, a herd of approximately 5,000 cattle would be required.

There are two main drawbacks to this type of processing:

- Processing equipment is expensive.
- Processed feed must be used rapidly or spoilage will occur.

## BY-PRODUCT FEEDS

### Grain By-product Feeds

For nutritional value to livestock, grain by-product feeds are similar to their grain sources or only slightly lower. Exceptions which are much higher in protein than the grain from which they originated are fibrous feeds, such as oat hulls and brans, and brewers' and distillers' dried grains. Most grain by-product feeds are good energy or protein sources. However, sometimes the cost of supplying energy through grain by-product feeds is higher than through the grains in original form.

Most milling by-products tend to contain higher levels of crude protein, neutral detergent fiber, ash, calcium, and phosphorus than their original grain sources. Milling removes the nutritious bran layers, which are used for livestock feed, and processes the less nutritious, inner starchy part of the grain for human consumption. However, these by-products are not complete feeds. They must be supplemented to compensate for their protein, mineral, and vitamin deficiencies.

***Hominy feed*** is a by-product of the manufacture of pearly hominy, hominy grits, or table corn meal for human consumption. It consists of a mixture of corn bran, the corn germ, and varying amounts of the starchy parts of the corn kernel.

- Hominy feed is made from both white and yellow corn. The label on hominy feed bags must state whether yellow or white corn was used.
- Yellow hominy feed has a slight amount of carotene (Vitamin A).
- Hominy feed contains about the same feeding value as No. 2 shelled corn.
- It can serve as a substitute for yellow corn, but the price per pound should be equal to or lower than the price of No. 2 shelled corn.
- When hominy feed replaces corn in swine finishing diets, it produces softer carcasses.

***Wheat middlings*** is a by-product of the milling of flour. It consists of fine particles of bran, the wheat germ, the aleurone layer, and coarse flour in varying amounts. It is usually considered more a swine feed than a cattle feed. However, it can be satisfactorily fed to any livestock.

- Wheat middlings contains more protein and slightly less metabolizable energy than does corn.
- Wheat middlings is a good source of phosphorus for ruminants, though the phosphorus content is less than in wheat bran.
- Wheat middlings is fine-textured and tends to become gummy when eaten; thus it is usually fed to swine.
- It is high enough in total protein for swine diets, but lacks certain essential amino acids that must be supplemented for swine.

***Wheat bran***, like wheat middlings, is a by-product of the milling of flour. It consists mainly of the seed coat of wheat, which is removed in the milling of wheat flour.

- Wheat bran is palatable to all kinds of livestock.
- Wheat bran has about the same energy content as oats.
- It can be substituted for oats in swine breeding diets where bulk and a slight laxative effect are desired.
- Wheat bran contains slightly more protein and more phosphorus than oats do.
- It is usually limited to about 10 percent of the diet because of its bulkiness and laxative effect.

***Dried bakery products*** consist of stale bakery products and other bakery wastes. The products are blended together and ground into a meal.

- The blending of dried bakery products can be controlled so that the end product is similar to corn in feeding value.
- Dried bakery products are usually much higher in fat and salt than corn is.
- Dried bakery products can be substituted for corn, but should be limited to about 20 percent of the diet.
- Nutritional composition can vary greatly depending on the source of the dried bakery products. Therefore, a feed analysis should be done before using these products in a livestock diet.

### Non-Grain Plant By-product Feeds

***Dried beet pulp*** is a product of the sugar refining industry and consists of beet tops and crowns.

- Beet pulp is fed mainly to cattle.
- It is high in fiber but is very palatable to cattle.
- As a source of energy, it is usually more expensive than corn.
- But beet tops are high in oxalic acid, which may interfere with calcium absorption. Thus, calcium should be added to the diet when beet pulp is fed.

***Cane molasses and beet molasses*** are two kinds of molasses used as livestock feeds.

- Cane molasses contains no digestible protein, and beet molasses, a very small amount.
- The energy from molasses comes mainly from the sugar it contains. Sugar energy is no more valuable than starch energy.
- Both beet and cane molasses are very palatable to livestock. When molasses is added to a diet, livestock may consume more feed.
- As a source of energy, molasses is usually more expensive than corn.
- Molasses reduces dustiness when added to feeds that tend to be dusty.
- It stimulates microbial activity in the reticulo-rumen.
- It provides many microminerals and possibly unidentified factors essential to animals.
- Molasses should not comprise more than 5 to 10 percent of the diet.

## *Protein Concentrates*

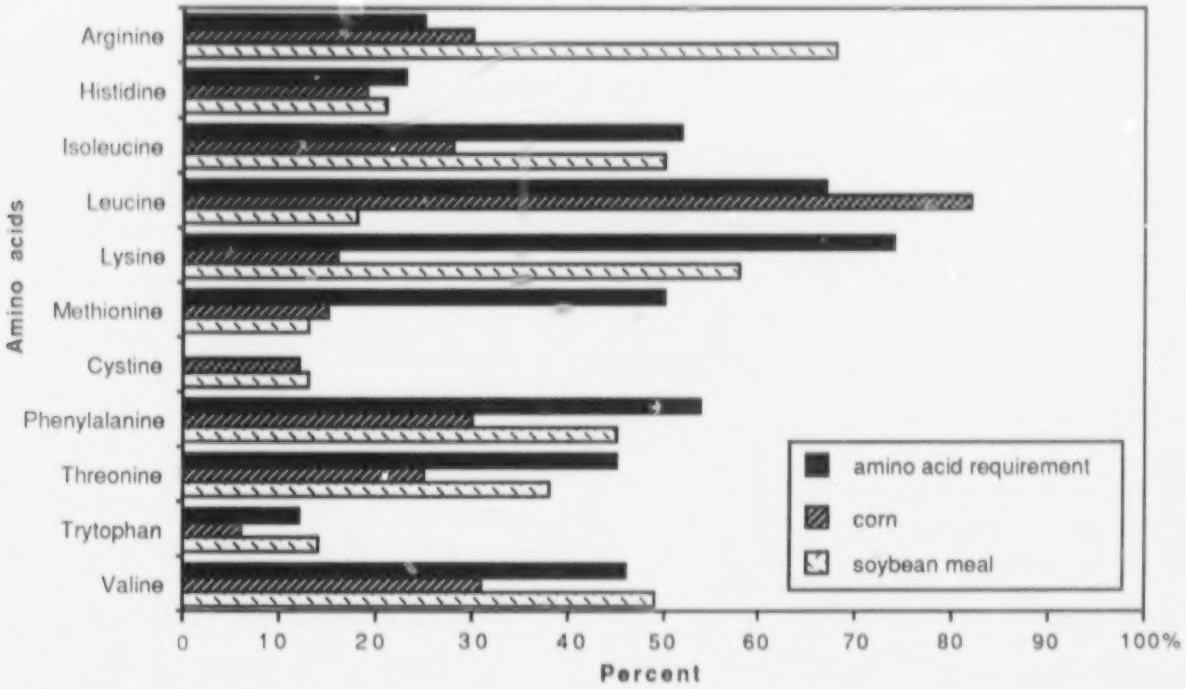
Protein concentrates are those feed materials which are added to a diet to raise its protein content. Except for maintenance diets, grains and roughages usually do not provide enough protein. Protein concentrates come from both plant and animal sources.

### Protein Concentrates of Plant Origin

***Soybean meal*** makes up over 60 percent of the protein supplement fed in the United States. It is the single most important protein supplement for livestock diets. Soybean meal consists of soybeans which have been ground to a meal after the oil has been removed.

- Soybean meal is very palatable to cattle, sheep, and swine.
- Soybean meal can serve as the only protein supplement for cattle.
- In combination with corn, it contains the required amino acids for swine (Figure 84).
- Ohio and most other midwestern states have soybean processing plants nearby. Thus, soybean meal is usually less expensive due to lower transportation costs.
- For cattle, sheep, and swine, corn and soybean meal can provide all that is needed for grain and protein supplement of a concentrate diet. Usually, mineral and vitamin supplements are all that need to be added.
- The two grades of soybean meal are 49 and 44 percent protein.
  - 49% soybean meal is produced from dehulled soybeans.
  - 44% soybean meal has had the hulls added back.

Amounts of essential amino acids (+ cystine) contributed by corn and soybean meal in a 16% corn-soy diet compared to the requirements for a growing pig (weaning to 75 lb). **Figure 84**




*(Data from Iowa State University)*

***Corn gluten feed and corn gluten meal*** are by-products of the manufacture of corn starch and corn syrup.

- Corn gluten feed contains corn bran and is about 25 percent protein.
- Corn gluten meal has a very high protein content of about 60 percent.
- Much of corn gluten meal protein bypasses digestion in the rumen. Thus, it is often fed to cattle.
- It is often fed to poultry at 5 to 10 percent of the diet.
- Because the protein of these two feeds is of the same quality as that of corn, neither would add any protein variety or quality to a diet already high in corn.

***Distillers' grains*** are a by-product in the manufacture of distilled liquors and alcohol. Because several different grains may be used, the nutrient content of distillers' grains may vary.

- If distillers' grains have a favorable price compared to other protein supplements, one-fourth of the total supplement can be from distillers' grains.
- Due to the high fiber content, distillers' grains are seldom fed to swine and poultry.
- Distillers' grains are deficient in the amino acid lysine.

***Brewers' grains*** are a by-product of the manufacture of beer. They can be obtained in either wet or dry form. Wet brewers' grains are usually more available in the vicinity of a brewery.

- Dried brewers' grains contain about 26 percent protein; wet brewers' grains about 6 percent protein.
- Brewers' grains are satisfactory feed for cattle, sheep, and swine. Wet brewers' grains are more often fed to cattle than to sheep or swine.
- Due to their high fiber content, these grains are seldom fed to swine and poultry.
- Brewers' grains have a poorer amino acid balance than soybean meal does, but better than distillers' grains.

***Linseed meal*** is made from flax seed after the oil is extracted. It is a good protein supplement but is deficient in several of the essential amino acids. Thus, it is not as suitable for a swine protein supplement as soybean meal is.

- Linseed meal is believed by some feeders to make cattle hair coats sleek and glossy. (No research has as yet confirmed this.)
- Usually linseed meal provides protein at higher cost per pound than soybean meal.
- Linseed meal has a slightly laxative and tonic effect on swine. Hence, it is often used in brood sow diets.

***Cottonseed meal*** is what remains of cottonseed after the oil is extracted.

- For cattle, cottonseed meal can serve as the only protein supplement (i.e., if the price is favorable compared to soybean meal).
- Cottonseed meal often carries varying amounts of a substance called *gossypol*, which has a poisonous effect on swine.
- Cottonseed meal is deficient in lysine.

## Protein Concentrates of Animal Origin

***Tankage*** is a by-product of the meat packing industry. It consists of unusable animal tissue including bones and dried blood. It is cooked under pressure, partially defatted, dried and ground.

***Meat scrap*** is similar to tankage except that it is cooked in its own fat and not under pressure. Dried blood is not usually added. It has somewhat better protein quality than tankage.

***Tankage with bone and meat and bone meal*** are similar to the above two feeds except that extra bone has been added. This increases the calcium and phosphorus content and reduces the protein content somewhat.

- These products are finely ground, dried residues from animal tissues not including hair, hoofs, horns, manure, stomach contents, and hide trimmings.
- Tankage and meat and bone meal are high protein supplements usually used in swine diets.
- Tankage and/or meat and bone meal are usually mixed with soybean meal as a part of the supplement.
- These products are not as palatable as soybean meal. One-third of the soybean meal of a diet can be replaced with tankage or meat and bone meal if the comparative costs justify it.
- Tankage and meat and bone meal are low in the amino acid tryptophan when compared to soybean meal.
- Meat and bone and blood meal are sometimes fed for their bypass protein value even if the cost is higher than for soybean meal.

***Two fish meals*** are usually available for use as swine supplements–menhaden fish meal and anchovy fish meal. Both are satisfactory protein supplements, equal to or slightly better than tankage or meat and bone meal.

- Fish meal is a good protein supplement for swine. Cost comparison with soybean meal should determine whether fish meal should be used.
- One-third of the total protein supplement can be made up of fish meal.
- Fish meal is usually high in calcium and phosphorus.
- It is also high in bypass crude protein.

***Milk products*** are dried buttermilk, dried skim milk, and dried whey. These products are usually fed to swine. They contain all the essential amino acids and essential vitamins for swine.

- Dried skim milk and buttermilk contain about 33 percent protein; dried whey contains about 14 percent protein.
- Cost of milk products is usually too high compared to other swine supplements such as soybean meal or a commercial concentrate.
- Dried milk products are used for feeding young dairy calves and are usually sold as calf-milk replacer. These products are mixed with water.

## Commercial Protein Concentrates

High protein concentrates are formulated by commercial feed companies. They are available for mixing with grains to formulate a balanced diet. The principal nutrient contained in these feeds is crude protein. In addition, most also contain supplemental minerals and vitamins. The nutrients provided by these feeds should be those not readily available on the farm.

Commercial protein concentrate feeds are prepared for each species of livestock. Usually the feeds will be formulated to meet the nutritional needs for each life-cycle phase of the livestock being fed, i.e. growth, pregnancy, and lactation.

Since swine cannot digest fiber efficiently, the protein concentrates prepared for swine should be checked for their fiber content. The feeder should be able to rely upon these feeds to provide all the essential amino acids required by swine.

Since ruminants have the ability to synthesize the required amino acids and B complex vitamins in their digestive tracts, the need for complex protein concentrates can be questioned.

For the most part, farm-grown roughages and grains can, when needed, be adequately supplemented with soybean meal. The decision as to whether to purchase complete commercial protein concentrates or to purchase soybean meal plus mineral and vitamin premixes for mixing with farm-grown grains should depend on the relative cost of each.

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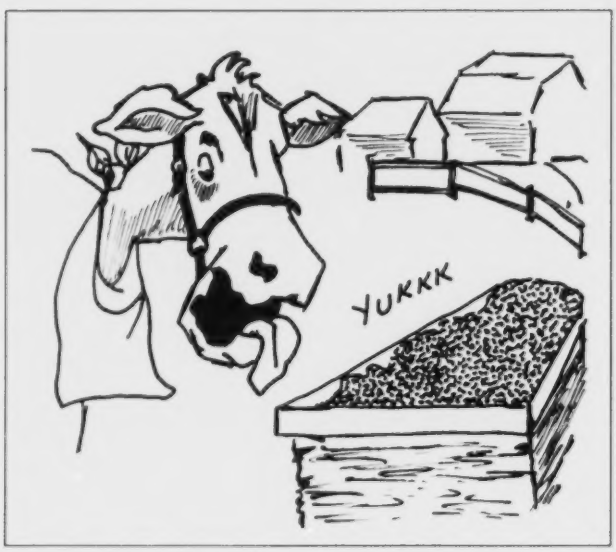
**Figure 85**

Urea included in a feed must be well mixed with the other ingredients and in proper amounts so that it is palatable to livestock.
*(Cornell University)*

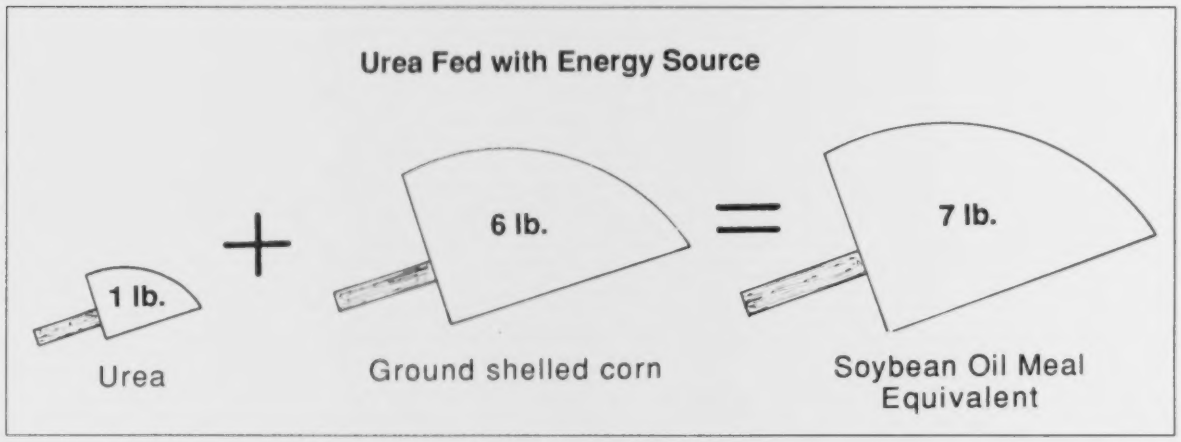



IMPORTANCE OF NONPROTEIN NITROGEN (NPN) - UREA

Ruminants can use nitrogen in two basic forms: pre-formed protein (such as soybean meal) and non-protein nitrogen (NPN). Urea is a good NPN source of protein. When fed to ruminants, urea breaks down quite rapidly, releasing ammonia ($NH_3$). Rumen microorganisms are able to use the nitrogen in ammonia to form microbial protein (which is digested to release amino acids that are absorbed into the blood stream). The digestive system of nonruminants lacks the microorganisms needed to convert urea into usable protein.

But urea by itself is unpalatable to cattle when fed in too high amounts (Figure 85). The right amount of urea to include in a feed is critical to its palatability, and it must be well mixed with the feed. Grain diets should contain less than 1.5 percent urea. Also, urea should be mixed only with grain containing less than 15 percent moisture to avoid the formation of ammonia ($NH_3$). Too high a concentration of ammonia will lower palatability and also become toxic to the animal. To prevent this and to make it more palatable, the feed should also include grain that will provide sugars, or dry molasses, along with the urea (Figure 86).

When large amounts of urea are fed to ruminants, grain must also be included in the diet to avoid ammonia toxicity. **Figure 86**




Research studies have shown that adding urea to corn silage at the time of ensiling provides an efficient way of feeding urea (Figure 87). Adding 10 pounds of urea per ton of silage increases the crude protein content. Also, the low-level consumption of urea mixed with corn silage, over a long period of time, eliminates its toxicity problems. About 10 percent more urea can be fed through silage than through the concentrate mixture.

Urea is a satisfactory source for part of the protein in a dairy cow diet. Even higher production results when an additional protein source such as soybean meal is used along with urea. (See Table 19.)

**Figure 87**

A non-protein nitrogen source is being automatically added by a metering device as the silo is being filled. This ensures thorough mixing of the non-protein source with the silage. *(Michigan State University Agricultural Experiment Station)*

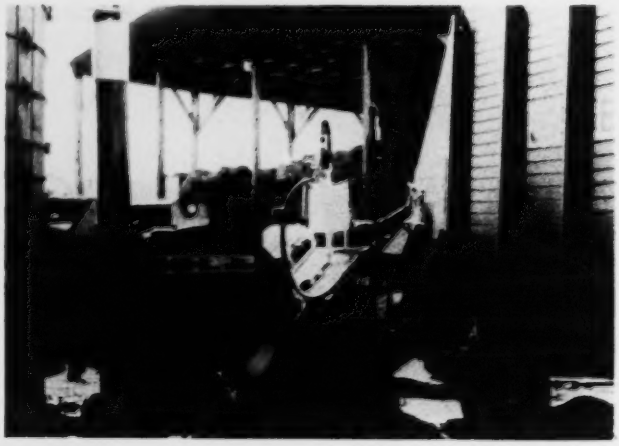


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**Table 19** Feed consumption and performance of dairy cows fed corn silage, urea-corn silage, and corn silage-soybean meal diets

| DIETS<br>Roughage | Corn Silage | Urea<br>Corn Silage | Urea<br>Corn Silage | Corn Silage |
|---|---|---|---|---|
| Concentrate | Corn | Corn | Corn<br>Soybean Meal | Corn<br>Soybean Meal |
| Protein - Total diet (%) | 8.5 | 10.5 | 12.5 | 13.6 |
| FEED INTAKE | | | | |
| Corn silage per day (lb) | 42.0 | 50.0 | 56.0 | 56.0 |
| Corn silage dry matter per day (lb) | 14.5 | 16.8 | 19.1 | 19.7 |
| Total dry matter per day (lb) | 29.5 | 31.8 | 36.6 | 33.7 |
| Crude protein intake (lb) | 2.4 | 3.6 | 5.3 | 6.0 |
| PERFORMANCE | | | | |
| Milk per cow daily (avg. lb) | 42.2 | 52.2 | 58.1 | 56.5 |
| **Change per day in body weight** (lb) | –1.1 | –0.2 | +0.4 | +1.1 |

*Source: Agricultural Extension Service, Michigan State University*

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The protein contributed by urea in commercial supplements is expressed on the feed label as percent crude protein from non-protein nitrogen. (See Figure 88.) This can be converted to percent urea by dividing by 2.81. In this example, the equivalent crude protein from NPN is 35.0 percent. 35 divided by 2.81 equals 12.45 percent urea. Protein supplements vary considerably in their urea content. Therefore, the appropriate content in the diet should be calculated to avoid feeding an excessive amount of urea. This is of special importance when corn silage is the main source of roughage.

When urea provides a part or all of the protein in a diet, the nitrogen-sulfur ratio should not be greater than 15:1. As much as 4 pounds of elemental sulfur per ton of concentrate may need to be added.

## Selecting Protein Concentrates

### *For Cattle and Sheep*

Livestock producers usually have a choice of several protein concentrates. The most important consideration in their selection should be which concentrate supplies protein economically. The cost per unit of protein should be the main determining factor.

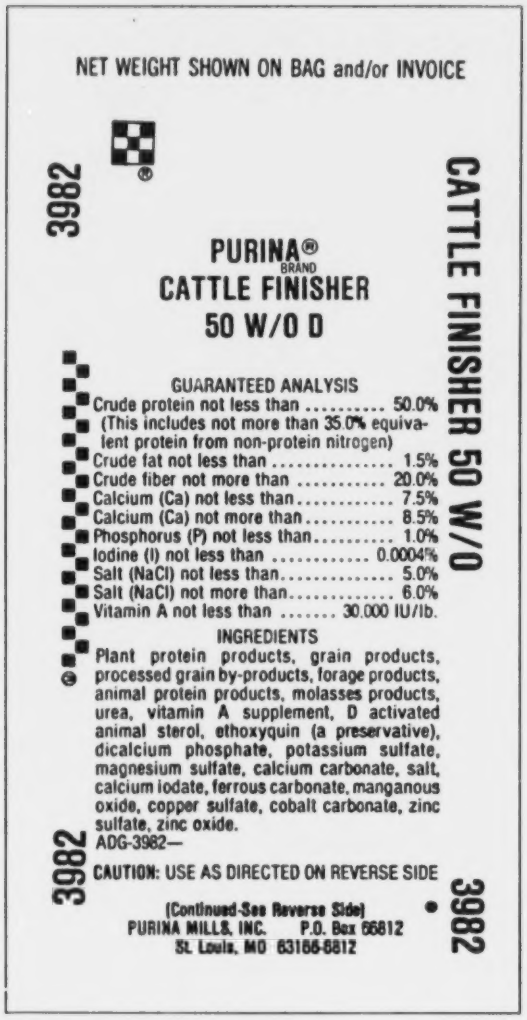
NET WEIGHT SHOWN ON BAG and/or INVOICE
3982
PURINA®
BRAND
CATTLE FINISHER
50 W/O D
GUARANTEED ANALYSIS
Crude protein not less than ..... 50.0%
(This includes not more than 35.0% equivalent protein from non-protein nitrogen)
Crude fat not less than ..... 1.5%
Crude fiber not more than ..... 20.0%
Calcium (Ca) not less than ..... 7.5%
Calcium (Ca) not more than ..... 8.5%
Phosphorus (P) not less than ..... 1.0%
Iodine (I) not less than ..... 0.0004%
Salt (NaCl) not less than ..... 5.0%
Salt (NaCl) not more than ..... 6.0%
Vitamin A not less than ..... 30,000 IU/lb.
INGREDIENTS
Plant protein products, grain products, processed grain by-products, forage products, animal protein products, molasses products, urea, vitamin A supplement, D activated animal sterol, ethoxyquin (a preservative), dicalcium phosphate, potassium sulfate, magnesium sulfate, calcium carbonate, salt, calcium iodate, ferrous carbonate, manganous oxide, copper sulfate, cobalt carbonate, zinc sulfate, zinc oxide.
ADG-3982—
CAUTION: USE AS DIRECTED ON REVERSE SIDE
[Continued-See Reverse Side]
PURINA MILLS, INC. P.O. Box 66812
St. Louis, MO 63166-6812
CATTLE FINISHER 50 W/O
3982
3982

**Figure 88**

This label for a commercial supplement states the percentage of equivalent protein supplied by urea (non-protein nitrogen) *(arrow)*.

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Following is an example which may help you in making your determinations: ***Example***

1) 42 percent digestible protein and 46 percent digestible protein soybean meal (*as-fed* basis) are available. The cost per ton of each is:
42% - $298.00
46% - $323.00
Which is the most economical to buy?

2) If 42 percent digestible protein soybean meal sells for $298.00 per ton, how much can you afford to pay for a 46 percent digestible protein soybean meal?

*Calculation procedure:*

$$\frac{.42}{298} = \frac{.46}{x}$$

$$.42x = .46 \times 298$$

$$.42x = 137.08$$

$$x = 326.38$$

On a protein equivalent basis, a 42 percent soybean meal costing $298.00 per ton would be equal in value to a ton of 46 percent soybean meal costing $326.38 per ton.

3) There is another factor to consider.

- It requires fewer pounds of the 46 percent than of the 42 percent digestible protein soybean meal to balance a ton of complete feed.
- If 16 percent digestible protein is required in the diet, 60 pounds more ear corn (corn and cob meal) will be required. The cost of the extra corn should be charged to the 46 percent soybean meal (as-fed basis).
- If ear corn is worth 3 cents per pound, 60 pounds would be worth $1.80 (.03 x 60 = 1.80), and a ton of 46 percent digestible protein soybean meal would be worth $328.18 per ton. ($326.38 + $1.80 = $328.18)

### *For Swine*

Swine, unlike ruminants (as described in Unit 3), cannot synthesize ten of the amino acids in sufficient quantity to provide maximum growth and performance. So it is important that the feeds making up the diet contain these ten essential amino acids. Selection of a protein concentrate for swine should be determined by

- the amount of the ten essential amino acids supplied, and
- the comparative cost of concentrates.

Table 20 shows the effect of feeding 20-pound young pigs a lysine-deficient diet. Note that the deficiency of lysine in the second diet (sorghum-peanut meal) reduced the daily gain of the pigs as well as the daily feed intake.

**Table 20**

20-pound young pig performance when fed a lysine-deficient diet

| *Diet* | | | *Pig Performance* | |
|---|---|---|---|---|
| Type of Diet | Dietary Lysine % | Dietary Protein % | Daily Gain lb | Daily Feed Intake lb |
| Sorghum-soybean meal | 1.07 | 20.2 | 1.19 | 2.28 |
| Sorghum-peanut meal | 0.54 | 20.2 | 0.55 | 1.54 |

*Source: Pork Industry Handbook, PIH 5,* Protein and Amino Acids for Swine. *Cooperative Extension Service, The Ohio State University*

If there are two or more protein concentrates that supply the required amino acids, the most economical choice should be determined by the cost per pound of protein supplied. This can be determined by the same procedure as used previously for cattle and sheep.

Usually protein concentrates are variable in their amino acid content. Table 21 gives the relative value of different protein concentrates in swine diets. In general, these ratings reflect the value of the various concentrates in replacing up to half of the soybean meal in a corn-soybean meal diet containing 16 percent protein. All the concentrates listed contain as much methionine as does soybean meal, or more. Tryptophan is not likely to be deficient when the diet contains at least 10 percent soybean meal. The replacement value of the concentrates is calculated from their ability to provide lysine.

| Supplement | Relative Value % | Pounds Equal to One Pound Soybean Meal |
|---|---|---|
| Soybean meal (45% protein) | 100 | 1.00 |
| Soybean meal (50% protein) | 104 | 0.96 |
| Cottonseed meal | 86 | 1.16 |
| Linseed meal | 81 | 1.23 |
| Fishmeal (menhaden) | 118 | 0.85 |
| Meat and bone scrap (50% protein) | 101 | 0.99 |
| Tankage (60% protein) | 110 | 0.91 |
| Blood meal | 123 | 0.81 |
| Skim milk, dried | 96 | 1.04 |

**Table 21**

Relative value of various sources of protein for swine diets.

*Source: Cooperative Extension Service, University of Illinois*

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*Example:* (using Table 21 data) ***Example***

How much linseed meal would it take to replace 1/2 of 45 percent protein soybean meal?

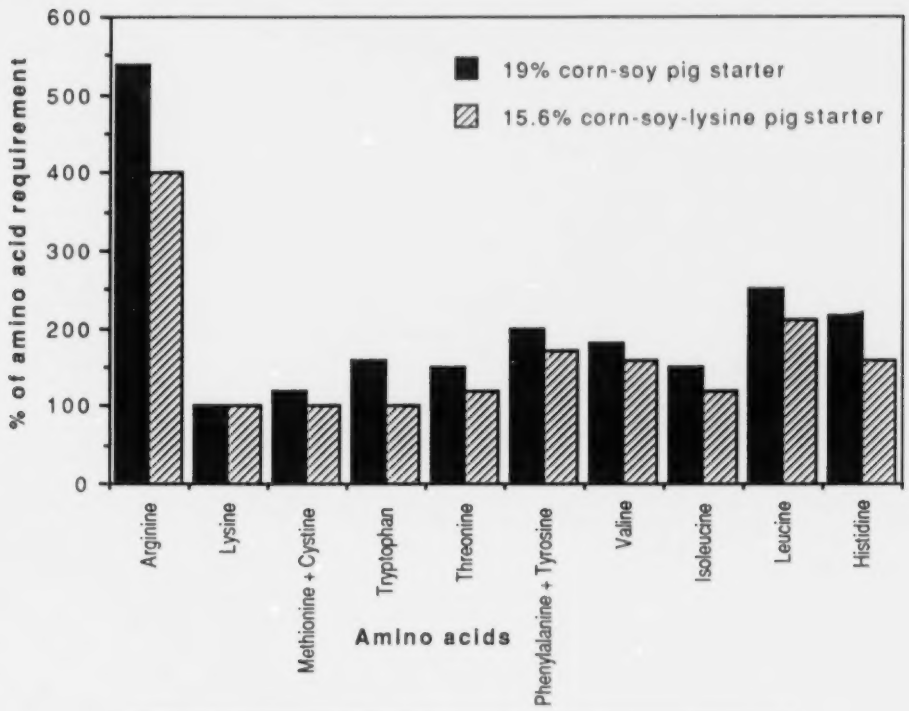
A 16 percent protein diet of corn and soybean meal would contain 80 pounds of corn and 20 pounds of soybean meal. (Half of 20 = 10 lb.) Because it takes 1.23 pounds of linseed meal [from table] to replace 1 pound of soybean meal, it would take 12.3 pounds of linseed meal (10 x 1.23 = 12.3). Thus, the 12.3 pounds of linseed meal would have to cost no more than 10 pounds of 45 percent soybean meal to be of equal value.

---

When balancing the essential amino acid content of the swine diet, one should be careful to avoid supplying excessive amounts of some amino acids while bringing others up to the required amounts. For example, supplying sufficient lysine with a corn-soybean meal diet will result in an oversupply of arginine. Such an unbalanced amino acid diet causes poor use of amino acids by the body. (See Figure 89.) Other combinations of protein concentrates or synthetic amino acids may be used in achieving a balanced amino acid diet.

Crystalline lysine hydrochloride (lysine HCl) contains 78 percent pure lysine. Three pounds of this product mixed with 97 pounds of corn in a 14 percent finishing diet can be used to replace 100 pounds of soybean meal. If more than 100 pounds of soybean meal per ton is replaced, a shortage of tryptophan will start to appear. Synthetic tryptophan can be used. Synthetic amino acids can also be used as part of vitamin and mineral premixes. To prevent deterioration of the amino acids, such mixes should not be stored for long periods of time.

**Figure 89** Formulating diet to reduce excess amino acids




*(Source: Koenig, Steve E., "Formulating Swine Rations, Practical Applications of Amino Acid and Energy Requirements,"* Animal Nutrition and Health, *Vol. 36, No. 4, May 1981. California Farmer Publishing Company, 83 Stevenson St., San Francisco, CA 94105)*

## Supplements

Supplements are feeds that are added to the roughage and concentrate parts of an animal's diet to supply ***minerals*** and ***vitamins*** that are lacking in the mixture.

### *Minerals*

Minerals are inorganic elements that make up a small percentage of livestock diets. However, their importance to the health of livestock cannot be overemphasized. The feed materials used in formulating diets may vary widely in their mineral content.

- Concentrate diets consisting of corn and soybean meal are low in calcium.
- Corn silage and grass hays are low in calcium.
- Most forage crops are low in phosphorus.

The calcium and phosphorus content of forage crops will vary considerably depending upon the calcium and phosphorus content of the soil on which they are grown. Also, the loss of leaves during the curing process reduces the calcium and phosphorus content of the hay since much of it is located in the leaves.

Each diet should be carefully evaluated for its mineral content. The minerals that are commonly deficient in the diet are calcium, phosphorus, and salt. These will need to be added. Table 22 gives the minerals required and their common sources. (Other minerals are present in feeds, but may not be available in a form usable by the animal.)

Individual minerals in an animal's diet may interact with other minerals or vitamins in the diet. The lack or oversupply of one mineral or vitamin in the diet may cause another mineral to be ineffective. If these small amounts of minerals in the diet are handled carelessly, certain mineral elements can easily be overfed. This results in

- a toxic (poisonous) effect on the animal,
- reduced productivity,
- excessive mineral residue passed on for human consumption, and
- possible accumulation of minerals in the soil.

Therefore the livestock feeder should be careful not to overfeed or underfeed any of the mineral elements. (See Chapter 6 and the nutrient requirement tables in the Appendix for safe levels of minerals to feed.)

---

**Table 22**

Sources of minerals for supplementing diets

| Mineral | Source |
|---|---|
| Calcium | Ground limestone, rock phosphate, tricalcium phosphate |
| Calcium and phosphorus | Dicalcium phosphate, defluorinated phosphate, steamed bone meal |
| Phosphorus (available) | Monosodium and disodium phosphate, monoammonium phosphate |
| Sodium and chlorine | Salt |
| Sulfur | Potassium sulfate, magnesium sulfate |
| Potassium | Sometimes adequate; for lactating cows- potassium chloride, potassium sulfate |
| Iodine | Iodized salt, trace mineralized salt, and trace mineral mixes |
| Iron (baby pigs) | Iron injections, clean soil, pills or paste containing iron |
| Zinc | Usually adequate in natural feeds; if not, zinc carbonate, zinc sulfate, trace mineralized salt |
| Cobalt | Usually adequate in natural feeds; in certain areas trace mineralized salt necessary |
| Magnesium | Magnesium oxide |
| Copper | Copper sulfate, copper oxide |
| Manganese | Manganese sulfate, manganese oxide |
| Selenium | Sodium selenite provided in feed or by intramuscular shot |

- A calcium deficiency is most likely to occur with animals on a high concentrate diet.
- A phosphorus deficiency is most likely to occur on a high roughage diet.
- A magnesium deficiency is most likely to occur in spring on lush pastures.

A good home-mixed mineral supplement for ***high roughage feeding*** would be one which contains equal parts by weight of dicalcium phosphate and trace mineralized salt (TMS). This mix contains approximately 12 percent calcium, 9 percent phosphorus, and 50 percent trace mineralized salt.

A good home-mixed mineral supplement for ***high concentrate feeding*** would consist of equal parts by weight of dicalcium phosphate, finely ground limestone, and trace mineralized salt. This mixture contains approximately 20 percent calcium, 6 percent phosphorus, and 33 percent salt.

Minerals usually can be fed either free-choice or mixed with the concentrate. Homemade mineral feeders can be used for free-choice feeding of minerals and salt (Figure 90). Note that limestone and TMS should be mixed in the supplement first. Or use an intake-limiting block (usually with salt as the limiter).

### *Calcium to Phosphorus Ratio and Milk Fever*

In the diet of dry (non-milking) cows the ratio of calcium to phosphorus is important. A high amount of calcium relative to the amount of phosphorus can cause milk fever at calving. Calcium levels should be lowered to under 100 grams per day during the dry period and phosphorus to under 75 grams. An option is to feed cows 20-30,000,000 IU of Vitamin D less than a week before calving to lower the risk of milk fever.

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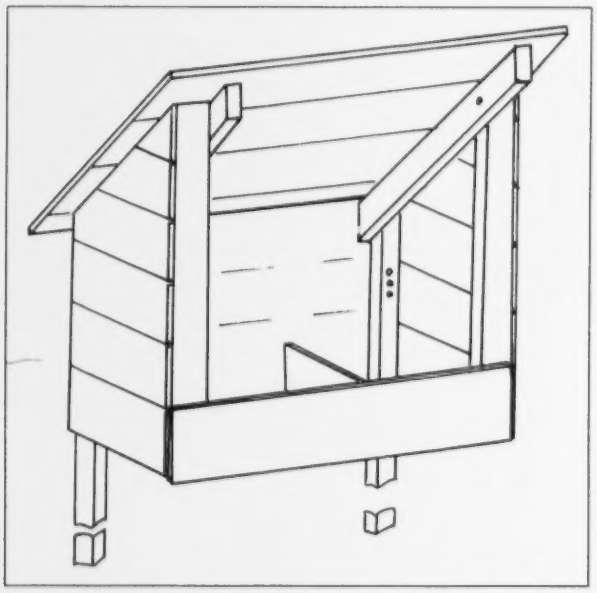
**Figure 90**

A homemade mineral feeder for free-choice feeding of minerals and salt



Research indicates that a desirable ratio to prevent milk fever is 1.5 to 2 parts calcium to 1 part phosphorus (if enough phosphorus is provided). High quality alfalfa or other legume hay may contain 1 to 2 percent calcium and 0.2 to 0.3 percent phosphorus. This gives a diet of 5 to 10 parts calcium to 1 part phosphorus. Grass hay has a better calcium to phosphorus ratio of about 2:1. Substituting grass hay for part of the legume hay would narrow the ratio. Also, when calcium levels are too high in grass hay, extra phosphorus can be provided through a mineral supplement. When cows are dry, no legume hay should be fed.

### *Magnesium Deficiency and Grass Tetany*

A condition known as ***grass tetany***, or ***grass staggers***, sometimes occurs in cattle and sheep. The cause is a deficiency of magnesium in the animal's system. Affected animals exhibit such symptoms as twitching of the skin, staggering or unsteadiness on their feet, and even falling and being unable to rise.

Grass tetany occurs most often in spring when animals are grazing on rapidly growing, succulent pasture. Though magnesium may be adequate, research indicates that a high level of potassium in the grass interferes with magnesium absorption by the animals. In summer, when the growth rate of grass decreases, potassium levels also decrease. So, more magnesium can be absorbed. Also, the soil in some areas, such as southeastern Ohio and much of the grazing land of West Virginia, does not contain enough magnesium. When magnesium is needed, it should be provided through magnesium oxide in block form or mineral mix.

Grass tetany is most likely to affect dairy cattle that are producing milk, and beef cattle and sheep that are producing young. The production of milk, which contains magnesium, apparently deprives the animals of part of the magnesium needed for other body functions. Feeding supplemental magnesium prevents the problem (Figure 91). Affected animals can be saved by injection of magnesium and calcium salts in solution.

One last problem is that sheep seem especially prone to copper toxicity. So it is very important that minerals fed to sheep be kept completely separate from minerals fed to cattle.

---

**Figure 91**

Magnesium-salt blocks (in boxes) can be strategically placed near a watering spot for beef cattle to help prevent grass tetany.

**Mineral and Vitamin Requirements for Beef Cattle** (see Table 23)

FREE-CHOICE MINERAL MIXTURES*

*Mixture 1.* For the cow herd during breeding season to provide extra phosphorus.

| | % of Mix | % Ca | % P |
|---|---|---|---|
| Trace mineralized salt | 33 | -- | -- |
| Bonemeal or dicalcium phosphate | 67 | 22-27 | 13-18 |
| TOTAL IN MIX | 100 | 14.7-18.0 | 8.7-12.8 |

*Mixture 2.* For the cow herd before and after breeding season.

| | % of Mix | % Ca | % P |
|---|---|---|---|
| Trace mineralized salt | 50 | -- | -- |
| Bonemeal or dicalcium phosphate | 50 | 22-27 | 13-19 |
| TOTAL IN MIX | 100 | 11.0-13.5 | 6.5-9.5 |

*Mixture 3.* For cattle in drylot on grain or other feedstuffs low in calcium content.

| | % of Mix | % Ca | % P |
|---|---|---|---|
| Trace mineralized salt | 33.3 | -- | -- |
| Bonemeal or dicalcium phosphate | 33.3 | 22-27 | 13-19 |
| Ground limestone | 33.3 | 38 | -- |
| TOTAL IN MIX | 100.0 | 20.0-21.7 | 4.3-6.3 |

*Mixture 4.* For feeding to herds during late winter and early spring in areas where grass tetany (magnesium deficiency) is a problem. No other salt or mineral mixture should be offered, or daily magnesium intake may be too low.

| | % of Mix | % Ca | % P | % Mg |
|---|---|---|---|---|
| Magnesium oxide | 25 | -- | -- | 60 |
| Trace mineralized salt | 25 | -- | -- | -- |
| Bonemeal or dicalcium phosphate | 25 | 22-27 | 13-19 | -- |
| Ground corn | 25 | -- | 0.35 | -- |
| TOTAL IN MIX | 100 | 5.5-6.8 | 3.3-4.8 | 15.0 |

*Commercial Mixtures.* Salt-mineral mixtures comparable to those listed may be purchased commercially. Beware of mineral blocks that are extremely hard because it is very difficult for cattle to obtain their daily mineral requirements from such blocks.

*Feeding Salt and Mineral Separately.* To ensure adequate intake of salt and all other mineral elements, consider feeding Mixture 1, 2, or 3 in one feeder and straight trace mineralized salt in another feeder.

*How to Feed Mineral Mixes.* All salt or mineral mixes should be fed under cover to keep out rain and/or snow. When fed outside, weather-vane type feeders that rotate with the wind are the most desirable. They may be constructed at home or purchased commercially. Mineral feeders should be located in sites where cattle have daily contact.

*How to Budget Mineral Consumption.* When fed free-choice, cattle will consume approximately 0.1 to 0.2 lb of salt-mineral mix per head per day. A figure of 0.15 lb per day or 55 lb per cow per year would be a rough average

* *Source: Ohio Cooperative Extension Service, The Ohio State University*

Mineral and vitamin requirements of beef cattle **Table 23**
(in percentage of ration dry matter or amount per pound of dry ration)

| Vitamins & Minerals | Growing and Finishing Steers and Heifers | Dry Pregnant Cows | Breeding Bulls and Lactating Cows |
|---|---|---|---|
| Vitamin A activity IU* | 1000 | 1300 | 1800 |
| Vitamin D activity IU | 125 | 125 | 125 |
| Vitamin E activity IU | 10-25 | --- | 10-25 |
| Minerals | | | |
| Sodium | 0.1% | 0.1 | 0.1 |
| Calcium | 0.18-0.60% | 0.18 | 0.18-0.29 |
| Phosphorus | 0.18-0.43% | 0.18 | 0.18-0.23 |
| Magnesium | 400-1000 mg | --- | --- |
| Potassium | 0.6-0.8% | --- | --- |
| Sulfur | 0.1% | --- | --- |

*May be Vitamin A or Provitamin A

*Adding Vitamin A to Mineral Mixes.* Adding a Vitamin A premix to the mineral mix is a convenient method of providing this vitamin. However, Vitamin A loses its potency with time, so these mixes should not be stored for extended periods of time. Enough Vitamin A should be added to the mineral mix so that each animal receives its requirement (10,000 to 50,000 IU) in 0.1 to 0.2 lb of total mix.

### Minerals for Swine

The mineral content of a swine diet will be affected by the concentrates used. As previously stated, a diet of corn and soybean meal is low in calcium. Although corn contains phosphorus, it is largely in a form unavailable to swine. Thus, mineral supplements must be supplied in corn-soybean meal diets.

Protein supplements such as tankage and fishmeal are high in both calcium and phosphorus. Alfalfa meal and milk by-products (skim milk and buttermilk) are high in calcium. The amount of calcium and phosphorus supplied through a mineral supplement should be reduced if animal or milk source protein supplements replace soybean meal.

Commercial swine concentrates are mineral-fortified. When mixed with grains according to the manufacturer's recommendations, these concentrates normally supply the needed amounts of minerals. The following mineral mixture will adequately supply enough minerals when mixed with a ton of corn-soybean meal diet:

20 pounds ground limestone,
20 pounds dicalcium phosphate or steamed bone meal, and
10 pounds trace mineral salt (high zinc - 0.8%).

This mixture contains approximately 26 percent calcium, 5.5 to 7.0 percent phosphorus, and 20 percent salt.

### *Problems with Mineral Balance in Swine Diet*

Many kinds of animals can consume nutrients in greater amounts than the required minimum with no ill effect. This is not true with swine. For example, growing-finishing pigs that are fed levels of calcium in the diet that are higher than they need often experience a decrease in gain and a higher feed rate per pound of gain.

Another problem that may arise is development of the nutritional disease *parakeratosis*. This results when high levels of calcium (over 0.8 percent) and inadequate levels of zinc are combined. Parakeratosis gives the animal a mangy look. Its skin becomes dry and scaly, particularly on the hind legs, tail, and underside of the body. The condition can be corrected by keeping the level of calcium below 0.8 percent or by adding 90 grams of zinc per ton of a complete diet. Trace mineralized salt containing 0.8 percent zinc may also be used. (Additional minerals should not be mixed in the diet when a commercial supplement is used unless the tag says to do so.)

Research conducted on sows at The Ohio State University indicates that selenium added to the diet at 0.3 ppm lowers the incidence of environmental mastitis and retained placentas.

Problems sometimes arise when swine are fed free-choice. They may overeat or undereat the minerals they need. To be certain that swine meet, but do not exceed, their requirement, minerals should be fed in a completely mixed diet. Tables 24 and 25 give the minerals required and the amounts to include in swine diets for pigs from birth to market weight and for reproducing swine. Table 26 lists the feed ingredients that supply calcium or calcium and phosphorus. Table 27 gives an example of a micromineral premix.

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**Table 24**

Required minimal mineral concentrations in diets for pigs from birth to market weight (% or ppm)

| | Liveweight (lb) | | | | | |
|---|---|---|---|---|---|---|
| **Mineral** | **2-10** | **10-20** | **20-45** | **45-80** | **80-130** | **130-220** |
| Calcium,% | 0.90 | 0.80 | 0.65 | 0.60 | 0.55 | 0.50 |
| Phosphorus,%† | 0.70 | 0.60 | 0.55 | 0.50 | 0.45 | 0.40 |
| Sodium,% | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Chlorine,% | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| Potassium,% | 0.30 | 0.26 | 0.26 | 0.23 | 0.20 | 0.17 |
| Magnesium,% | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Iron, ppm | 150 | 140 | 80 | 60 | 50 | 40 |
| Zinc, ppm | 100 | 100 | 80 | 60 | 50 | 50 |
| Copper, ppm | 6 | 6 | 5 | 4 | 3 | 3 |
| Manganese, ppm | 4 | 4 | 3 | 2 | 2 | 2 |
| Iodine, ppm | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| Selenium, ppm | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |

† At least 40% of the phosphorus should be provided by inorganic sources.

Adapted from NRC, 1978, *Nutrient Requirements of Swine*, National Academy of Sciences, Washington, DC

## Table 25

Required minimal mineral concentrations in diets for reproducing swine (% or ppm)

| Mineral | Bred gilts & sows Young & adult boars | Lactating gilts & sows |
|---|---|---|
| Calcium,% | 0.75 | 0.75 |
| Phosphorus,%† | 0.50 | 0.50 |
| Sodium,% | 0.15 | 0.20 |
| Chlorine,% | 0.25 | 0.30 |
| Potassium,% | 0.20 | 0.20 |
| Magnesium,% | 0.04 | 0.04 |
| Iron, ppm | 80 | 80 |
| Zinc, ppm | 50 | 50 |
| Copper, ppm | 5 | 5 |
| Manganese, ppm | 10 | 10 |
| Iodine, ppm | 0.14 | 0.14 |
| Selenium, ppm | 0.10 | 0.10 |

† At least 40% of the phosphorus should be provided by inorganic sources.

*Source of all three tables:* Cooperative Extension Service, The Ohio State University, PIH 52, *Minerals for Swine.* Adapted from NRC, 1978, *Nutrient Requirements of Swine,* National Academy of Sciences, Washington, DC

## Table 26

Feed ingredients that supply calcium or calcium and phosphorus

| | %Ca | %P | Lb needed to equal P in 1 lb. of dical phos. | Lb change in limestone * for each lb. change of dical phos. | Lb of dical substitute and limestone per ton of feed when completely replacing dical | |
|---|---|---|---|---|---|---|
| Grd. limestone (Ca carbonate) | 38* | 0 | | | Dical subs. | Limestone* |
| Dical phos. | 22 | 18 | | | | |
| Monocal phos | 16 | 24 | 0.75 | +.25 | 15 | 25 |
| Mono-dical phos | 18 | 21 | 0.86 | +.20 | 17 | 24 |
| Defluor rock phos | 32 | 18 | 1.00 | -.25 | 20 | 15 |
| Steam bone meal | 24 | 12 | 1.50 | -.35 | 30 | 13 |
| Trical phos | 38 | 18 | 1.00 | -.40 | 20 | 12 |
| Meat & bone meal | 10 | 5 | 3.60 | -.35 | 72 | 13 |
| Tankage | 6 | 3 | 6.00 | -.35 | 120 | 13 |
| Fish meal | 6 | 3 | 6.00 | -.35 | 120 | 13 |

* If ground limestone contains 35% Ca, multiply pounds change in limestone by 38/35 or 1.09.

## Table 27

Example of a micromineral premix (3 lb) to be added to 1 ton of feed

*Suggested ingredients:* ferrous sulfate; zinc oxide, carbonate or sulfate; copper oxide, hydroxide, carbonate or sulfate; manganese oxide, carbonate or sulfate; pentacalcium orthoperiodate; calcium or potassium iodate; sodium selenite or selenate.

| Ingredient | Concentration (per 3 lb ) |
|---|---|
| Iron | 40 gm |
| Zinc | 55 gm |
| Copper | 5.5 gm |
| Manganese | 11 gm |
| Iodine | 0.11 gm |
| Selenium | 90.8 mg |
| Carrier (such as ground corn) | To bring total to 3 lb |

## *Vitamins*

Most of the vitamins required by livestock are present in the required amounts in natural feeds. However, due to the importance of each vitamin for the well being of an animal, the livestock feeder should evaluate the vitamin content of each diet formulated.

As described in Unit 2, vitamins are divided into two groups:

- ★ Fat soluble vitamins - A, D, E, and K
- ★ Water soluble vitamins - the B complex vitamins and Vitamin C

Of these vitamins, K and C are synthesized in the digestive tract of swine, horses, cattle, and sheep. Thus, the feeder usually does not need to be concerned about them unless the feed is moldy. Moldy feed may cause a Vitamin K deficiency in swine.

### Vitamins for Cattle and Sheep

When cattle and sheep have access to good pasture during the summer and receive plenty of high quality roughage in winter, they are seldom in need of vitamin supplements.

***Vitamin A*** is required by all ruminants. Plants do not contain Vitamin A as such, but they contain carotenes that are converted to Vitamin A. Carotenes are very unstable and can be lost during storage. However, ruminants on pasture or being fed high carotene-content forages can store it in their liver for use when their diet is deficient. Vitamin A deficiency can occur in cattle and sheep under the following conditions:

- ✣ The roughage fed is of poor quality.
- ✣ The hay was bleached or rained on during curing.
- ✣ The hay was cut when overripe.
- ✣ Cattle and sheep graze pasture during a drought.
- ✣ Corn stover is eaten.

When such a Vitamin A deficiency exists with dairy or beef cattle, their diet can be corrected by supplementing it with a Vitamin A premix.

***Vitamin D*** deficiency is usually not a problem with cattle and sheep. Vitamin D is synthesized in the skin of animals exposed to direct sunlight. It is contained in sun-cured hays. Vitamin D deficiency occurs when animals that are kept in confinement are fed diets of silages or high levels of grain with inadequate Vitamin D. To play it safe, many dairy cattle feeders feed Vitamin D anyway.

***Vitamin E*** is supplied in adequate amounts in natural feedstuffs under most conditions. Wheat germ meal, dehydrated alfalfa meal, high quality legume hay, and some green feeds are good sources of Vitamin E. Vitamin E oxidizes rapidly when exposed to air. A low level of selenium in the diet increases the need for Vitamin E.

***B complex vitamins*** (water soluble) are synthesized in the rumen of cattle and sheep normally in sufficient quantities to meet the animal's needs. Because of their importance, B complex vitamins are sometimes added to the diet, as they improve milk protein and prevent certain nutritional diseases.

## Vitamins for Swine

### *Fat-Soluble Vitamins*

The fat-soluble vitamins the swine feeder should be concerned with are A, D, E, and sometimes K.

The ***Vitamin A*** needs of swine can be met by either Vitamin A or carotene. As already stated, Vitamin A does not occur in plant products. Swine, however, can convert the plant pigment carotene to Vitamin A in their intestinal walls. Good natural sources of carotene are green pasture and green leafy alfalfa hay or meal. Yellow corn also contains some carotene, but not in dependable quantities because much of it is destroyed in storage. When swine diets are formulated, the carotene content of corn is disregarded. Other cereal grains have little or no carotene.

***Vitamin D*** is produced by swine that have daily access to sunlight. However, pigs that are confined need fortification of their diet with Vitamin D. Except for sun-cured hays, most feedstuffs lack Vitamin D.

***Vitamin E*** deficiencies have shown up in swine raised in confinement on corn-soybean meal diets. Occasionally, the animals will show signs of anemia and jaundice. Severe Vitamin E deficiencies can result in sudden death of weaned pigs. Post-mortem examinations reveal liver damage.

Research studies indicate that reduced Vitamin E intake is due to decline in the use of pasture and the artificial drying of grain. Grains low in selenium increase the need for Vitamin E in the diet. The dietary content of one of these nutrients affects the requirements for the other. Supplying selenium in a micromineral mix usually reduces the Vitamin E requirement. Swine raised under commercial production conditions also may have marginal Vitamin E deficiencies. Though there may be no visible symptoms, the deficiency can cause a decline in production efficiency. The Vitamin E content of the diet should be checked to determine whether supplemental Vitamin E is necessary.

***Vitamin K*** occurs in many natural feedstuffs and is also synthesized in the digestive tract of the pig. However, a deficiency can be caused by moldy feeds. If needed, Vitamin K can be supplied by dehydrated alfalfa meal or by a synthetic Vitamin K compound.

### *Water-Soluble B Complex Vitamins*

Niacin, $B_{12}$, riboflavin, pantothenic acid, and choline are the ones that concern the swine feeder.

***Niacin*** in yellow corn and other grains is in a form that is largely unavailable to swine. Thus, feed grains are not credited with containing any niacin for swine diets. If a given diet is rich in the amino acid tryptophan, however, swine can convert it into niacin.

***Vitamin $B_{12}$*** has as its primary functions growth promotion and prevention of certain types of anemia. Natural sources of Vitamin $B_{12}$ include meat scraps, tankage, and fish meal. Many commercial synthetic products are available. Grains and plant products are poor sources of Vitamin $B_{12}$.

***Riboflavin*** promotes growth and aids in reproduction and the prevention of dermatitis (skin disorder). Natural sources include liver, milk products, and high quality alfalfa. Riboflavin is usually supplied by a supplement. Grains and plant by-products such as soybean meal are poor sources.

The function of ***pantothenic acid*** is to promote health and vigor. A severe deficiency results in a nervous disorder characterized by goose stepping or a jerky, uneven gait. (Refer back to Figure 48, page 57.) Sources of pantothenic acid are milk by-products, yeast, and calcium pantothenate. Corn and soybean meal are poor sources.

***Choline*** aids in growth and reproduction. Most natural ingredients contain sufficient choline. But if additional choline is needed, choline chloride can be added to the diet as a supplement. Diets low in the amino acid methionine increase the need for choline.

Natural sources of vitamins for swine are given in Table 28.

**Table 28**

Natural sources of vitamins for swine

| Vitamin | Sources |
|---|---|
| ***Fat Soluble*** | |
| A (carotene) | Alfalfa meal, good pasture, fish liver oils |
| D | Irradiated yeast, sun-cured hay, sunshine |
| E | Legume pasture, alfalfa meal |
| ***Water Soluble*** | |
| B complex (except $B_{12}$) | Alfalfa meal, distiller solubles, condensed fish solubles, milk by-products, good pasture |
| $B_{12}$ | Animal proteins, condensed fish solubles, distiller solubles |

## Synthetic Vitamins

The chemical structure of a vitamin remains constant regardless of the source of the vitamin. In other words, natural and synthetic vitamins are of equal value to the pig. Whenever the natural ingredients used in swine diets do not contain adequate amounts of vitamins, synthetic vitamins in a vitamin supplement should be added. Synthetic vitamins, produced by many companies, are sold individually or in various combinations of vitamins or as vitamin-mineral combinations. Often these can be purchased in quantities prepackaged to be added to 1 ton of feed.

The vitamin premix in Table 29 contains all the vitamins needed to be added to swine starter, gestation, or lactation diets (based on daily feed intake of 4-5 pounds during gestation and 9-12 pounds during lactation) when 5 pounds are added per ton of feed, and for growing and finishing diets by including 3 pounds per ton. Commercial complete feeds and protein supplements generally contain supplemental vitamins. Check to see if the levels are adequate. If not, add vitamins that are needed in appropriate amounts. Suggested vitamin additions per ton of feed are shown in Table 30.

**Table 29**

Suggested vitamin mix

| Ingredient | Amount/lb of premix |
|---|---|
| Vitamin A | 800,000 IU |
| Vitamin D | 80,000 IU |
| Vitamin E | 3,000 IU |
| Vitamin K (menadione)† | 660 mg |
| Riboflavin | 1,000 mg |
| Pantothenic acid | 4,500 mg |
| Niacin | 7,000 mg |
| Choline chloride‡ | 20,000 mg |
| Vitamin $B_{12}$ | 5 mg |

* Premix is designed to be used at a rate of 5 lb. per ton of complete feed for sows and baby pigs and 3 lb. per ton of complete feed for growing and finishing swine

† Menadione conversion values are as follows:
1 gm. of menadione = 3 gm. of menadione sodium bisulfite complex (MSBC) or
2 gm. of menadione dimethylprimidinol bisulfite (MPB) or
2.2 gm. of menadione sodium bisulfite (MSB)

‡ To meet the recommended level of choline in gestation and lactation diets, add 1.5 lb. of choline chloride (50% choline) per ton of diet

**Table 30**

Suggested vitamin additions per ton of feed

| Vitamin | Starter | Grower-finisher | Gestation-lactation |
|---|---|---|---|
| Vitamin A, IU | 4,000,000 | 2,400,000 | 4,000,000 |
| Vitamin D, IU | 400,000 | 240,000 | 400,000 |
| Vitamin E, IU | 15,000 | 9,000 | 15,000 |
| Vitamin K (menadione), gm | 3.3 | 2 | 3.3 |
| Riboflavin, gm | 5 | 3 | 5 |
| Pantothenic acid, gm | 22.5 | 13.5 | 22.5 |
| Niacin, gm | 35 | 21 | 35 |
| Choline, gm | 100 | — | 300 |
| Vitamin $B_{12}$, mg | 25 | 15 | 25 |

* Suggested levels are at least 150% of NRC recommended requirements with the exception of choline

*(Source of Tables 29 and 30: Cooperative Extension Service, The Ohio State University, PIH-2,* Vitamins for Swine)

### *Mixing Instructions*

The vitamin premix should be purchased from a commercial company. These suppliers have much better quality control and mixing facilities than do producers who handle small quantities of required vitamins. The amount purchased should be no more than can be used up in 3 to 4 months (or 3 months in hot, humid regions). Storage should be in a dry, cool area to reduce storage losses. Only enough feed for 3 to 4 weeks should be mixed at one time, as certain combinations of ingredients can increase vitamin loss over time.

Special care should be taken when adding vitamin premix to a feed to mix it thoroughly and distribute it throughout the feed. One method is to mix the vitamin premix for 1 ton of feed with about 20 to 50 pounds of finely ground corn or soybean meal and then add this to the total mixture in the mixer.

## Additives

Feed additives are non-nutrient products added to an animal diet to:

- improve rate of gain
- improve efficiency of feed use
- prevent certain diseases
- treat parasites

### *Commonly Used Feed Additives*

***Antibiotics*** are organic products which are synthesized by living organisms and which inhibit the growth of other organisms. Antibiotics improve animal performance by killing or inhibiting certain harmful microorganisms. Thus, the level of disease organisms in an animal may be kept low.

Disease-preventive antibiotics are often added to animals' diets to prevent the occurrence of specific diseases. Such additives should never be used in place of sound management practices.

***Antiparasite drugs*** are used to control infestations of different kinds of worms and coccidiosis.

***Hormones*** are released by specific glands in the body and carried by body fluids to other tissues in the body where they have a specific effect. Hormones are now synthesized commercially. They can be fed to animals or implanted.

Most of these products are strictly regulated by the United States Food and Drug Administration (FDA) to insure that their use will not harm consumers of animal products. These regulations change from time to time as new information and products become available. It is the responsibility of the feeder to be aware of current regulations and to observe them.

In addition to the FDA, the Ohio Department of Agriculture, Division of Plant Industry, Section of Feeds and Fertilizer requires that all additive products be labeled. The label gives information concerning the use of a given product. Labels should be read and followed when additives are used. The feeder must:

- Use feeds for the purpose intended.
- Follow directions given on the feed label.
- Heed warning statements on the label.
- Observe withdrawal periods, if any.
- Store medicated feeds properly.

(See page 139 for a discussion of feed regulations.)

Livestock nutrition now involves a large number of other additives that are not considered here. Remember as you formulate diets that you are responsible for reading and following the feed additive label. You stand to bear the penalty if regulations are not followed.

## Complete Feeds

Complete feeds are prepared off-the-farm in nearby feed mills. They provide a complete diet with all the nutrients required for the life-cycle phase of the feeder's livestock. Often these complete feeds are delivered by the feed mill directly to the feeder's bulk feed tank or feeders.

With this system, the livestock feeder:

- gives to the feed mill the responsibility for selecting quality ingredients and mixing them properly
- relies on the services of competent skilled labor, hired by the manufacturer, to prepare proper diets
- has less on-farm labor requirements
- has much less investment in feed handling and storage equipment
- can depend on the feed mill to make use of ingredients that are not readily available for on-farm mixing

The principal disadvantage of using complete feeds is their cost. Such feeds are estimated to cost $20.00 to $50.00 more per ton than on-farm-mixed corn-soybean meal feeds.

The livestock feeder must make the management decision concerning whether to purchase

- complete feeds that can be delivered directly to the storage bin, or
- soybean meal along with mineral and vitamin premixes to be mixed on the farm with home-grown corn.

# FEED MOISTURE CONTENT IN DIET FORMULATION

The feeder must know the moisture content of each feed ingredient in the diet and make adjustments for the differences in moisture content. Most feeds on hand are constantly changing in moisture content. Moisture changes affect the nutritional quality of a diet and also the value of a feedstuff in storage.

Two pieces of equipment are required in monitoring moisture content of feedstuffs and in making adjustments in the diet to compensate for moisture content changes. They are

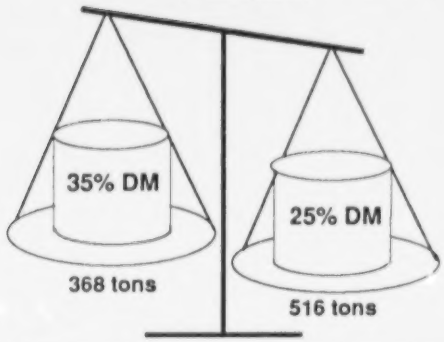
- a moisture tester to determine the moisture content of the feedstuff, and
- scales for weighing feed.

Using these two devices, the feeder can insure that livestock will receive a constant supply of each nutrient in the amount needed, regardless of changing moisture content.

## Dry Matter, Weight, Volume Relationships

The yield of silage crops per acre or the amount of silage in a silo is usually stated in total weight or tons of the crop. This is meaningless in terms of nutrient value unless the dry matter (DM) content of the crop is known. For example, a 25 percent DM load and a 35 percent DM load of corn silage may look alike, but the feed value is greater for the low moisture silage (35 percent DM).

**Figure 92** High moisture silage weighs much more than low moisture silage.




| Dry Matter Content of Silage | Tons of Silage In 20' x 54' Silo | Tons of Dry Matter In 20' x 54' Silo |
|---|---|---|
| 25% DM silage | x 516 tons | = 129 tons |
| 35% DM silage | x 368 tons | = 129 tons |

*Example*

1 ton 25% DM corn silage contains 0.25 x 2000 = 500 lb DM
1 ton 35% DM corn silage contains 0.35 x 2000 = 700 lb DM

This does not mean that the drier silage is better than the higher moisture silage in feed value. It just requires more pounds of the wetter silage to obtain the same amount of dry matter that is contained in the drier silage.

On the other hand, the weight of dry matter in corn silage per unit of volume is about the same regardless of the moisture content. For example, consider two silos, each 20 feet in diameter, each containing 54 feet of settled silage (Figure 92). One is filled with 25% DM and the other with 35% DM corn silage. The volume of corn silage and dry matter content are about the same in each silo. However, the high moisture silage weighs much more than the lower moisture silage.

Note that the feed value contained in each silo is about the same. This illustrates how important it is to consider the moisture content of feeds in formulating diets for livestock. This applies to all feedstuffs – silage, hays, grains, or concentrates.

## Moisture Content of Feeds

The amount of moisture in a given feedstuff influences the percentage of nutrients it contains. Feed composition tables consider moisture content of feeds in three different ways:

***As-fed*** - the nutrient content of feeds as they are normally fed to livestock. This can vary greatly depending upon the type of feed fed.

*For example:*
Shelled corn contains approximately 10% moisture.
Sun-cured hay contains approximately 15% moisture.
Silage contains approximately 70% moisture.
Pasture grass contains approximately 85% moisture.
Haylage contains approximately 50-55% moisture.

***Air-dry feeds*** - feeds that have been dried by the natural movement of air. This may be considered the actual amount of dry matter in a feed. More often it is assumed that air-dried feeds contain 90% dry matter.

***Oven-dry feeds*** - feeds that have been dried in an oven to obtain 100% dry matter (0% moisture).

### As-fed vs. Air-dry in Diet Formulations

Many cattle and sheep diets contain silages, high moisture grains, wet by-products, and other feedstuffs that vary greatly in their moisture content. Such diets are formulated on a dry matter basis. Then the quantity of each ingredient is converted to its ***as-fed*** weight, based on its dry matter content.

Swine diets are often formulated on an as-fed basis or an air-dry basis (90% DM). The reason for this is that most ingredients used in swine diets contain only small amounts of water. Nutrient requirement recommendations for swine are usually made on an air-dry basis (90% DM) and do not need to be converted to an as-fed basis, as you will learn in Chapter 6.

### Converting Feeds to Same Dry Matter Basis

When you are formulating livestock diets, be sure that you make comparisons of feeds on the same dry-matter basis.

✎ To change feeds on an as-fed basis to a moisture-free basis, the following formula may be used:

$$\frac{\%\text{ nutrient in wet feed}}{\%\text{ DM in wet feed}} = \%\text{ nutrient on dry basis}$$

*For example*, a given silage may contain 30% DM and 5% CP in the as-fed or wet basis. What is the percentage of CP in the silage on a dry basis? ***Example***

$$\frac{5\%\text{ CP (wet)}}{30\%\text{ DM (wet)}} = 0.1666 \times 100 = 16.7\%\text{ CP on dry basis}$$

✎ To change amounts of ingredients in a diet from as-fed basis to dry basis, use the following formula:

% ingredient in wet diet x % DM of ingredient = parts on dry basis

*For example*, a diet contains 65 lb grass silage with 30% DM and 35 lb ear corn with 90% DM. What are the proportions on a DM basis? ***Example***

| lb of Ingredients In Wet Diet | | DM in Wet Ingredients | | Parts DM in Diet | | Dry Matter Ingredients % |
|---|---|---|---|---|---|---|
| Grass silage - 65 lb | x 30% = | 19.5 lb | $\frac{19.5}{51}$ = | 38.2% |
| Ear corn - 35 lb | x 90% = | 31.5 lb | $\frac{31.5}{51}$ = | 61.8% |
| 100 lb | | 51.0 lb | | 100.0% |

✎ To change a dry-matter basis diet to as-fed basis, use the following formula:

$$\frac{\text{\% ingredient in dry diet} \times \text{\% DM desired in diet}}{\text{\% DM in ingredient}} = \text{parts of ingredient in wet diet}$$

*Example* *For example,* consider the above dry-matter basis diet with 38% grass silage and 62% ear corn. The desired as-fed diet contains 51% DM.

| Ingredients In Dry Diet % | | % DM Desired | | % DM in Ingredient | | Parts DM in Wet Diet | | % Ingredients in Wet Diet |
|---|---|---|---|---|---|---|---|---|
| Green silage - | 38% | x 51% | + | 30% | = | 64.60 | OR | 65% |
| Ear corn - | 62% | x 51% | + | 90% | = | 35.13 | | 35% |
| | 100% | | | | | 99.73 | | 100% |

## Formulating Diets on a Standard Moisture Basis

✎ To avoid errors in diet formulation caused by differing moisture contents of feed ingredients:

1) First formulate on the basis of
   - ✚ 100% DM (0% moisture)
   - or
   - ✚ 90% DM (10% moisture)
2) Then correct for moisture after the diet is properly balanced.

✎ To convert feeds in diets formulated on a dry matter basis (100% DM) to an as-fed basis, divide the total dry matter content of the feed contained in the diet by the percentage of dry matter in the feed.

lb DM in feed ÷ % DM in feed = lb feed as-fed

*Example* *For example,* a steer is fed 8 pounds of corn and cob meal dry matter and 8 pounds of corn silage dry matter. What is the as-fed weight of the diet when the corn and cob meal contains 87% DM and the corn silage 30% DM?

| | | DM Basis | As-fed Basis |
|---|---|---|---|
| Corn and cob meal | 87% DM | 8 lb | 8 ÷ 0.87 = 9.195 lb |
| Corn silage | 30% DM | 8 lb | 8 ÷ 0.30 = 26.666 lb |
| | | Total as-fed weight | 35.861 lb |
| | | | or **35.86 lb** |

# STATE LAWS REGARDING LIVESTOCK FEEDS

The livestock feeder should be aware that there are state laws regulating manufacture and distribution of commercial feed. The following are only a few examples adapted from the Ohio Revised Code* . You will want to consult your state's laws for more complete information.

## DEFINITIONS AND REGULATIONS OF THE LIVESTOCK FEED LAW

***Commercial feed*** means all materials distributed for use as feed or for mixing in feed for animals. Exceptions are:

- unmixed seed, whole or mechanically altered, made directly from the entire seed (such as corn, oats, etc.)
- unground hay, straw, stover, silage, cobs, husks, and hulls when not mixed with other materials
- individual chemical compounds when not mixed with other materials

The livestock feeder should be familiar with the following:

- Labels; required information
- Commercial Feed License
- Inspection fees; tonnage reports
- Analysis of samples
- Order to hold
- Seizure of feed; condemnation

### Labels; Required Information

***Label*** refers to any written or printed matter on the package or tag of feed containers or the printed invoice of feeds sold in bulk. (Figures 93 and 94 are examples of commercial feed labels.)

It is illegal for any person to distribute commercial feeds, except customer-formula feeds (see page 141), in bags or other containers unless the bags or containers have the following information placed on them or affixed to them on labels in plainly written or printed form:

1. Net weight of contents
2. Product name and brand name (if any)
3. Name and address of manufacturer or distributor
4. Guaranteed analysis of the feed
5. Name of each ingredient used in the commercial feed
6. Mixing and feeding directions
7. Any caution statement considered necessary by law

(On the commercial feed labels shown in Figures 93 and 94, identify each of the above.)

* *Ohio Revised Code*, Book 2

***Net weight*** is the amount in pounds printed on the bag or other container, or the amount in pounds or tons on the invoice of bulk feeds.

***Product name*** is the name of the commercial feed which identifies it as to kind, class, or specific use.

***Brand*** means any word, name, symbol, or device, or any combination thereof identifying the commercial feed of a distributor and distinguishing it from that of others.

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**Figure 93**

Label from a commercial horse feed.
Note that vitamins and minerals are included.

NET WEIGHT 50 POUNDS

## SHUR TONE FIRST PLACE 16% ROLLED HORSE FEED

GUARANTEED ANALYSIS

| | |
|---|---|
| Crude Protein, Minimum | 16.0% |
| Crude Fat, Minimum | 3.0% |
| Crude Fiber, Maximum | 5.5% |

INGREDIENTS

Corn, Rolled Oats, Wheat Middlings, Soybean Meal, Calcium Phosphate, Calcium Carbonate, Salt, Molasses (including animal fat & propionic acid), Vitamin A Acetate in Gelatin, Vitamin D3 Supplement, Vitamin E Supplement, Riboflavin Supplement, d-Calcium Pantothenate, Niacin, Vitamin B12 Supplement, Choline Chloride, Thiamine Mononitrate, Folic Acid, d-Biotin, Zinc Sulfate, Ferrous Sulfate, Copper Sulfate, Ethylenediamine Dihydriodide, Cobalt Carbonate, Sodium Selenite, Manganous Oxide and Rice Hulls.

MIXING AND FEEDING DIRECTIONS

Feed Shur Tone First Place as recommended below, adjusting amount fed depending on condition desired and activity of the horse.

**Foals to 1 year of age:** free choice up to 15 lbs. per head per day
**1 year to 2 years of age:** Feed up to 12 lbs. per head per day
**Racing or Training:** Feed 10-12 lbs. per head per day
**Mares in Foal:** Feed 5 lbs. per head per day. During the last 3 months feed up to 10 lbs. per head per day
**Moderate riding or activity:** Feed 5 to 8 lbs. per head per day
**Barren Mares, Idle Horses:** Feed 2-4 lbs. per head per day

*Amount fed will also be determined by quantity and quality of pasture or hay available. Feed salt free choice at all times. Feeding additional vitamins or supplements is not recommended.

Provide plenty of fresh clean water for the horses at all times.

Do not feed horses moldy or out of condition feed stuffs.

Manufactured by
The Ohio Grain Company
Milford Center, Ohio 43045

25-6100
20047

**Figure 94**

Label from a commercial sheep supplement.

NET WEIGHT 50 POUNDS

## SHUR TONE 36% ALL NATURAL SHEEP SUPPLEMENT

MEDICATED

**For growth promotion and feed efficiency. As an aid in reduction of losses due to enterotoxemia. Aids in reducing the incidence of vibrionic abortion in breeding sheep. Feed continuously during pregnancy.**

ACTIVE DRUG INGREDIENT

Chlortetracycline .....200 GM/TON

GUARANTEED ANALYSIS

| | |
|---|---|
| Crude Protein, Minimum | 36.0% |
| Crude Fat, Minimum | 1.0% |
| Crude Fiber, Maximum | 5.0% |
| Calcium, Minimum | 3.8% |
| Calcium, Maximum | 4.8% |
| Phosphorus, Minimum | 1.2% |
| Salt, Minimum | 2.2% |
| Salt, Maximum | 3.2% |

INGREDIENTS

Soybean Meal, Calcium Carbonate, Alfalfa Meal, Distillers Dried Grains/Solubles, Calcium Phosphate, Cane Molasses (including animal fat and propionic acid, a preservative), Salt, Potassium Sulfate, Magnesium Sulfate, Wheat Middlings, Magnesium Oxide, Vitamin A Acetate in Gelatin, Vitamin D3 Supplement, Vitamin E Supplement, Riboflavin Supplement, d-Calcium Pantothenate, Niacin, Vitamin B12 Supplement, Menadione Dimethylpyrimidinol Bisulfite (source of Vitamin K), Zinc Oxide, Ferrous Sulfate, Manganous Oxide, Ethylenediamine Dihydriodide, Cobalt Carbonate, Sodium Selenite and Rice Hulls.

MIXING AND FEEDING DIRECTIONS

Mix 36% All Natural Sheep Supplement with grain and feed as follows:

| | Supplement Lbs. | Grain Lbs. |
|---|---|---|
| Finishing Lambs | 250 | 750 |
| Gestating Ewes | 150 | 850 |
| Lactating Ewes | 300 | 700 |

Feed grain mixture to ewes at the rate of 1.5-2.5 lbs. per head per day. Amount fed will vary depending on ewe condition and number of lambs nursing.

Feed grain mixture free choice to finishing lambs. Keep feed before them at all times. Feed roughage free choice. Keep clean, fresh water available at all times.

Manufactured by
The Ohio Grain Company
Milford Center, Ohio 43045

19-2151
071188

(For example, in Figures 93 and 94 you can see these product names:
Shur Tone First Place 16% Rolled Horse Feed
Shur Tone 36% All Natural Sheep Supplement
On these labels the product and brand names are included together.)

***Name and address of the manufacturer*** of the feed must also appear on the label.

***Guaranteed analysis*** refers to:

- Minimum percentage of crude protein
- Minimum percentage of crude fat
- Maximum percentage of crude fiber
- Minimum and maximum percentages of calcium (Ca) and salt (NaCl)
- Minimum percentages of phosphorus (P) and iodine (I)

***Feed ingredient*** means each of the materials making up a commercial feed (such as grain products, processed grain by-products, plant protein products, etc.)

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**Customer-formula feed** means a mixture of commercial feeds, each batch of which is mixed according to the specific instructions of the final purchaser or contract feeder. These feeds, when delivered to the purchaser, must have with them an invoice stating the following information (Figure 95):

1. Name and address of the manufacturer
2. Name and address of the purchaser
3. Date of delivery
4. Product name and brand name, if any, of each commercial feed and all other ingredients used in mixture
5. Net weight of each commercial feed and of any other feed ingredient used
6. Directions for safe and effective use of feed that contains any drug
7. If drug-containing product used, statement of purpose of drug, name of each active drug ingredient, and amount of each drug used
8. Any caution statement considered necessary by law

**Bulk commercial feeds** - No person shall distribute a commercial feed in bulk unless the purchaser, on delivery, is supplied with a written or printed statement with the same information as required for customer formula feeds.

**Registration** - No person shall manufacture or distribute any type of commercial feed until a permit to manufacture or distribute has been obtained by the manufacturer from the department of agriculture.

**Tonnage inspection fee** - A licensee shall pay the director of agriculture an inspection fee at the rate of ten cents per ton for all commercial feeds distributed in the state except that portion of customer-formula feeds that is not commercial feed.

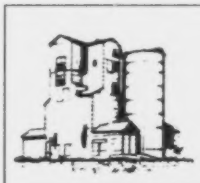
**Sampling and analysis** - The director of agriculture shall inspect and sample any commercial feed within the state to such an extent as deemed necessary and make an analysis where need is indicated to determine whether such commercial feed is in compliance with labeling and licensing regulations.

**Order to hold** - The director of agriculture may issue an order to the owner or custodian of any lot of commercial feed requiring it to be held at a designated place when the director has found the commercial feed to have been offered or exposed for sale in violation of any provisions of the livestock feed laws of the state.

**Seizure of feed; condemnation** - Any lot of commercial feed not in compliance with these feed laws is subject to seizure on complaint of the director of agriculture to a court of competent jurisdiction in the county in which the commercial feed is located.

**Figure 95**

An invoice from a lot of bulk feed. All feedstuffs included must be listed, as shown.



**D J FEEDS, INC.**
211 So. Jefferson Ave.
U.S. Route 42 S.
**PLAIN CITY, OHIO 43064**
Phone: (614) 873-4621

Vendor's No. _____ Date 10-30 19 90

Name Wayne Dellinger

Address RD. 2

| SOLD BY | CASH | C O D | CHARGE | ON ACCT | MDSE RETD | PAID OUT | |
|---|---|---|---|---|---|---|---|
| MB | ✓ | | | | | | |

| QUAN | DESCRIPTION | PRICE | AMOUNT |
|---|---|---|---|
| 1500 | Corn | | 89 25 |
| 200 | Soybean Meal | | 24 90 |
| 10 | Salt | | 80 |
| 10 | Mineral-(20-10) | | 3 00 |
| 150 | Wet Molasses | | 16 50 |
| | Crimp & Mix | | 6 75 |
| | | | 141 20 |

| | IN | OUT | BALANCE |
|---|---|---|---|
| CORN | | | |
| OATS | | | |

TOTAL

Medication _____ Withdrawal _____ Days

**TERMS:** All accounts due on 10th of month following purchase. Finance Charge of **2% PER MONTH** will be added to all past due balances. (Percentage rate **24% PER ANNUM**) **$.50 cent** minimum charge per month.

NO. 119112 REC'D BY _____

ALL CLAIMS AND RETURNED GOODS **MUST** BE ACCOMPANIED BY THIS BILL

## FEED ADDITIVES

Current regulations that govern the use of feeds with additives include:

- the level of additive permitted in the feed
- the species of livestock to which the additive can be fed
- the production stage of the particular animal
- the withdrawal period; i.e. the length of time established between withdrawing the additive from the feed and processing the animal product.

The USDA's Food Safety and Inspection Service conducts testing of animal products for the presence of additive residues. If illegal residues are found, a producer can face considerable economic loss. The product found in violation may be condemned. There is also a chance that the animals may be quarantined until they are proven free of the illegal substance.

### Mixing Additives with Feed

It is important to mix additives thoroughly with feed to ensure safe and effective use. A well-mixed batch of feed will prevent some animals' getting too much of the additive while others get too little. Either too much or too little can affect an animal's production and cause undesirable side effects. When a proper order is followed in mixing additives with feed, this problem can be avoided. A recommended mixing procedure is as follows:

1. Put in 1/2 of the supplement.
2. Add the additive and vitamin premixes.
3. Add 1/4 of the supplement.
4. Add any mineral premix.
5. Add the rest of the supplement.
6. Mix thoroughly.
7. Add ground grain.
8. Mix for 10-15 minutes, or longer than the equipment manufacturer's recommendation.

Always clean mixing equipment after mixing a batch of feed with regulated additives. Equipment can be cleaned by running 300 pounds of ground corn or soybeans through it. This feed should be labeled and stored for later mixing with additives.

### Recordkeeping

A good set of records can help producers avoid problems with feed contamination and residue problems in livestock and livestock products. Keep careful record of the following information:

1. the additive used
2. date the feed is mixed
3. amount of additive mixed
4. mixing time for each batch
5. location where the feed is stored
6. number, age, and weight of the animals fed from the batch and the amount given per head
7. date of cleaning mixers, bins, conveyors, and feeders

To complement this record, it is good to make a long-range plan for using additives, especially medications. Microorganisms and parasites have the potential to develop resistance to products used on a regular basis. Periodically changing the additives used reduces the chance of organisms' developing resistance to an additive. Good records of additives used over a period of time also helps veterinarians to treat animals properly when illness strikes.

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**Important biological concepts to learn from Unit 4:**

- ★ Not all feedstuffs are of equal value as feed for livestock; appropriate evaluative criteria must be applied when comparing feedstuffs.
- ★ Feeds are classified according to their chemical and physical characteristics.
- ★ Increasing the surface area of grain kernels by some processing method makes more of the grain kernel accessible to digestive juices when fed to livestock.
- ★ The nutrient content of some feeds is more concentrated than in other feeds.
- ★ The nutrients required by livestock are provided by plants and plant and animal by-products.
- ★ The moisture content of the individual feeds must be considered when comparing the nutritive value of two or more feeds.

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## REVIEW of Unit 4

After studying this unit, "Types of Feed and Their Composition," you should be able to answer and discuss the following.

1. What should the livestock feeder expect his or her feeding program to accomplish? *(page 86)*
2. What factors determine the value of a particular feed that might be included in an animal's diet? *(page 87)*
3. How can the kind of digestive tract of an animal affect the suitability of a given feed? *(page 87)*
4. Why is it important to consider the digestibility of a nutrient as well as the amount of the nutrient in a feedstuff? *(page 88)*
5. Give an example of the difference between a high quality feedstuff and a low quality feedstuff. *(pages 88-90)*
6. What single factor probably has the greatest effect on the nutrient content of a pasture crop? *(page 89)*
7. What is meant by a feed being ***palatable***? *(page 90)*
8. What are some of the factors affecting the palatability of a feed? *(pages 91-92)*
9. What is meant by the ***proportion of a feed*** that may be used in a given animal's diet? Give an example. *(page 92)*
10. How can the relationship of one feedstuff to another affect the diet that might be prepared for an animal? *(page 92)*
11. What are the different classifications of feedstuffs? From what kinds of feedstuffs does each come? *(pages 93-94)*
12. What distinguishes roughages from the other classifications of feedstuffs? *(page 95)*
13. List the principal legume crops raised in your area for livestock roughage feed.
14. How do roughages harvested from grass crops differ from those harvested from legumes? *(pages 95-97)*
15. What serious problem often occurs with use of tall fescue hay? What are some of the symptoms in affected animals? *(page 99)*
16. How do silages differ from other types of roughages? *(page 100)*
17. How does corn silage differ in feeding value from grass-legume silage? *(pages 100-101)*
18. Compare the feeding value of pastures with other sources of roughage. *(page 101)*
19. List the principal pasture crops raised in your area.
20. Inventory and evaluate the harvested roughage feeds available. First reproduce this form in your notebook. You then need to obtain a list of farm prices of roughages and be ready to make some estimates. List each kind of roughage available and fill in the information under each column heading given on the form.

INVENTORY AND EVALUATION OF ROUGHAGE FEEDS

| **Type of Roughage** (alfalfa hay, corn silage, etc.) | **Growth Stage Harvested** (hay full bloom, silage, dough stage, etc.) | **Harvesting Conditions** (rain, days to cure, etc.) | **Condition of Roughage** (bleached, % of leaves lost, etc.) | **Estimated Nutrients** | | **Estimated Value per Ton** |
|---|---|---|---|---|---|---|
| | | | | **Crude Protein %** | **ME Mcal per lb.** | |
| ***Example:*** *Red clover, timothy hay, 1/2 each* | *Red clover in full bloom; timothy spikes have seeds forming* | *Rained 1 time; needed 4 days to cure* | *Slightly bleached appearance; 10% of clover leaves lost* | *10* | *1.74* | |

21. Inventory and evaluate the pasture crops available. First reproduce this form in your notebook. Be ready to make some estimates. List each kind of pasture available and fill in the information under each column heading given on the form.

| Kind of Pasture | Limed or Fertilized (in last 5 years) | Growth Condition | Number of Acres | Kind of Animals to be Grazed | Number of Animals to be Grazed |
|---|---|---|---|---|---|
| | | | | | |

22. What distinguishes concentrates from roughages? *(pages 102-103)*
23. What are the two classes of concentrate feeds? *(page 102)*
24. What are the principal energy concentrates available to you?
25. What is meant by relative feeding value of a grain in comparison to corn? *(pages 105-107)*
26. What are some of the factors affecting the relative feeding value of a grain? *(pages 105-106)*
27. You would like to add some oats to your swine diet. If corn is worth $2.56 per bushel, what would be the comparative value of a bushel of oats?
28. On the day that corn was quoted at $2.56 per bushel in northwestern Ohio, oats was quoted at $2.73 per bushel. Could a northwestern Ohio swine feeder afford to include oats in the swine diet? Explain.
29. What are some of the factors that reduce the value of oats as a feed for swine? *(page 104)*
30. Organize the information regarding the grains available to you. First reproduce this form in your notebook. Use local feed prices:- farm prices if the grain is available on the farm; feed store price if the grain will be purchased. List each grain and fill in the information under each column heading given on the form.

| Kind of Grain | Condition of Grain Farm Produced | ESTIMATED AMOUNTS OF NUTRIENTS | | | | | | Value per CWT | Amount Available on Farm | Suitability as Livestock Feed | Amino Acid Content | Feed Preparation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TDN | NDF | ME | DE | DP | CP | | | | | |
| ***Example:*** | | | | | | | | | | | | |
| *Rye* | *Contains about 10% chaff and a few weed seeds* | 70% | 65% | 1396 *k cal/ lb* | 1.3 *Mcal/ lb* | 8% | 10% | $5 | 50 *bu* | *Not suitable for horses. Not more than 20% total grain diet for other livestock.* | *Low in trypto-phan* | *Coarse to medium grind. Feed whole to young cattle and ewes.* |

***Abbreviations:***
TDN = total digestible nutrients
NDF = neutral detergent fiber
ME = metabolizable energy
DE = digestible energy
DP = digestible protein
CP = crude protein

31. List the purposes of processing grain for feeding livestock. *(page 107)*
32. What are the two goals of the feeder in processing grain? *(page 107)*
33. What are the principal processing methods used by livestock feeders in preparing grain for their livestock? *(page 107)*
34. Why does grinding grain often increase its digestibility? *(page 108)*
35. List the grain by-product feeds available to you. Briefly describe how each is prepared.
36. Why do grain by-product feeds often contain more nutrients than the portion of the grain used for human food? *(page 111)*
37. List the non-grain plant by-product feeds available in your area.
38. Organize the information regarding grain and non-grain plant by-product foods available to you. First reproduce this form in your notebook. Use local feed prices. List each available by-product feed and fill in the information under each column heading given on the form.

| Kind of By-product Feed | Protein % | NUTRIENTS AVAILABLE | | | | | Essential Amino Acids | Cost per CWT | Avail-ability | Suitability as Livestock Feed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ME M cal/lb | CP % | Ca % | P % | NDF % | | | | |
| | | | | | | | | | | |

39. What distinguishes protein concentrates from energy concentrates? *(pages 103, 112)*
40. What are the two main classifications of protein concentrates? *(page 112)*
41. List the protein concentrates of plant origin that are available in your area.
42. List the protein concentrates of animal origin that are available in your area.
43. Briefly describe non-protein nitrogen as a source of protein in livestock feeds. *(pages 116-117)*
44. Why is non-protein nitrogen unsatisfactory as a source of protein for swine? *(page 116)*
45. Why must an energy feed be fed with a non-protein nitrogen source of protein for ruminants? *(pages 116-117)*
46. How can you tell whether a commercial protein concentrate contains a non-protein nitrogen source of protein? *(page 118)*
47. What is the most important factor to consider in selecting a protein concentrate for cattle and sheep? Explain. *(page 118)*
48. What is the most important factor to consider in selecting a protein concentrate for swine? Explain. *(page 120)*

49. Organize the information regarding protein concentrates used in livestock feeds. First reproduce the following form in your notebook. Then obtain prices from your local feed store. List protein supplements and fill in the information under each column heading given on the form.

| Kind of Protein Concentrate | Protein Content | | Essential Amino Acid Content | Cost per CWT | Cost per lb Protein | Mineral Content | | Availability | Suitability to Livestock |
|---|---|---|---|---|---|---|---|---|---|
| | Crude % | Digestible % | | | | Ca % | P % | | |
| ***Example:*** *Cottonseed meal* | 41.6 | 34.5 | *Lacks tyrosine Low in lysine* | $14.50 | $0.42/lb *digestible protein* | 0.15 | 1.10 | *Yes* | *Suitable for livestock* |

50. Why are supplements sometimes used with the roughage and concentrate parts of an animal's diet? *(page 122)*
51. What are the two main classifications of supplements that may be added to the animal's diet? *(page 122)*
52. In feeding cattle what macro mineral of a high concentrate diet is likely to be low in supply? *(page 124)*
53. In feeding cattle what macro mineral of a high roughage diet is likely to be low in supply? *(page 124)*
54. Why is it desirable for the diet of high-producing dairy cows to maintain a ratio of 1.5 to 2 parts calcium to 1 part phosphorus? *(pages 124-125)*
55. What mineral deficiency causes grass tetany in cattle and sheep? Under what conditions would you expect to find this disease? *(page 125)*
56. What macro minerals are usually in low supply in corn and soybean meal diets for swine? *(page 127)*
57. What kinds of swine concentrates are usually high in calcium and phosphorus content? *(page 127)*
58. How can low mineral content in swine diets be corrected? *(page 127)*
59. What mineral deficiencies cause the disease parakeratosis in swine? *(page 128)*
60. How can the livestock feeder be sure that a given diet formulated for the livestock being fed contains adequate vitamins? *(page 130)*
61. Why are the fat-soluble Vitamin K and the water-soluble Vitamin C usually no problem in formulating diets for cattle, sheep, and swine? *(page 130)*
62. What kind of diet for cattle and sheep would you expect to have a deficiency of Vitamin A? *(page 130)*
63. What conditions might bring on a deficiency of Vitamin D for cattle and sheep? *(page 130)*
64. Why are B complex vitamins no problem when feeding cattle and sheep? *(page 130)*
65. Why should swine feeders be concerned about the supply of the fat-soluble vitamins A, D, E, and K in the diets usually formulated for their swine? *(page 131)*
66. What mineral is related to the use of Vitamin E in the body? *(page 131)*

67. What are ***synthetic vitamins?*** *(page 132)*
68. Why are feed additives often used in formulating diets for livestock? *(page 134)*
69. What precautions should be followed when including feed additives in livestock diets? *(page 134)*
70. Describe the three different ways that feed composition tables may report the moisture content of feedstuffs. *(pages 136-137)*
71. In formulating diets for livestock, why is it important to make comparisons of feedstuffs on the same dry matter basis? *(pages 137-138)*
72. If the corn you are feeding your swine contains 86% dry matter (DM) and 8.7% crude protein (CP) on an as-fed basis, what is the CP content of this corn on a dry basis?
73. If a swine diet as-fed contains 1500 pounds (79%) of corn with 89% DM and 400 pounds (21%) of soybean meal with 90% DM, what are the portions on a DM basis?
74. Change the DM diet of problem 73 back to an as-fed basis with 78.8% corn and 21.2% soybean meal. The diet on an as-fed basis contains 89.2% DM which is the desired DM content.
75. A certain feed mixture contains 8 pounds of high moisture corn dry matter and 2 pounds of soybean meal dry matter. What is the as-fed weight of the mixture when the high moisture corn contains 77% dry matter and the soybean meal contains 89% dry matter?
76. What feed materials are not commonly covered by commercial feed laws? *(page 139)*
77. What information must the feed manufacturer provide on the feed tag or label? *(page 139)*
78. What action can authorities take when commercial feed laws are broken? *(page 142)*

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UNIT 5

# METHODS and PROCEDURES for DETERMINING NUTRIENT REQUIREMENTS and SELECTING BALANCED DIETS

## APPLIED ACADEMIC AREAS

### Biological science

- Identify the nutrient requirements for each stage of the animal's life
- For specific animals, formulate a diet that provides all the required energy and food nutrients in the amounts required to maintain the body and support the activity of the animal
- Recognize the importance of having all the ingredients of a given feed formulation thoroughly mixed to insure that animals are receiving the intended balanced diet
- Judge accurately what an animal's feed consumption will be in a single day
- Determine whether appropriate amounts of different feed ingredients are included in a feed formula

### Terms to know

ad libitum
auger
avoirdupois weight
coefficient
creep feeding
diet analysis
farrowing
feed bunk
self-fed
transponder

### Mathematics

- Use addition, subtraction, multiplication, division
- Work with parts of the whole
  - fractions
  - decimals
  - percentages
- Use ratio and proportion
- Measure weights - metric and avoirdupois; convert from one to the other
- Employ data analysis - read and interpret nutrient requirement tables
- Determine equivalent values
- Determine percentages of each ingredient in a given feed
- Determine amounts of an ingredient in a mixture when the percentage contained is known
- Set automatically controlled feeding devices
- Use the square method in determining proportions of feeds in a mixture
- Use algebraic equations
- Use simultaneous algebraic equations

## INTRODUCTION

In simple terms, a feed diet is the amount of feed provided an animal for one day. Usually two or more feedstuffs will be included in the diet. In formulating a diet, the relationship of one feedstuff to another must be considered. In some feeding situations, however, the feed consists of only one feedstuff.

The purpose of this unit is to provide you with the methods used in selecting, balancing, and formulating diets for livestock. Hopefully, this will enable you to plan a ***balanced*** diet (as shown in Unit 6) for the livestock you are going to feed. A balanced diet is one that supplies all the nutrient needs of the particular animal. Factors that must be considered when formulating a balanced diet are:

- The selection of feed materials (Unit 4)
  - nutrient content
  - palatability
  - availability
  - suitability to the kind of livestock
  - cost
- The nutrient requirement of the livestock to be fed
- The method of feeding to be used

As a result of studying Unit 5, you should be able to do the following:

1. Explain the meaning of each column and row heading as provided in the livestock nutrient requirement tables in the Appendix.
2. Determine the nutrient requirements of:
   a) livestock for maintenance when age, weight, and kind of livestock are known.
   b) livestock for providing growth and finishing when age, weight, kind of livestock, and growth rate are known.
   c) livestock during the gestation period when age, weight, kind of livestock, and time during the gestation period are known.
   d) livestock during the lactation period when age, weight, kind of livestock, and number of nursing young are known.
   e) lactating dairy cows when pounds of milk and butterfat percentage are known.
   f) the breeding male when extent of breeding activity is known.
3. Be familiar with the methods used and the mathematics involved in calculating balanced diets.
4. Select a procedure for balancing the diet of your livestock as determined by the method of feeding used.

# METHODS OF FEEDING LIVESTOCK

Before you can accurately select a diet, you must decide on the method of feeding to use for your livestock. This decision should take into consideration:

- the kind of livestock
- number of livestock
- feeding equipment available
- roughages used - pasture, silage, hay

Usually livestock are fed by one of these methods or a combination of them:

- Hand feeding
- Self-feeding (Figure 96)
- Automatic feeding

## Hand Feeding

Livestock that are hand fed are given a certain amount of feed daily. If a small number of animals is involved in your SAE (Supervised Agricultural Experience) program, you will probably use hand feeding. You will need to keep accurate records of the feed supplied.

In hand feeding livestock, the amount of feed to be fed daily as a balanced diet is predetermined. Livestock that are often hand fed are:

- Sows or gilts during the gestation period. (During the gestation period, weight gain must be controlled. Overweight sows and gilts often have problems at farrowing time – difficult births, stillborn pigs, and small pigs.)
- Dairy cows when fed the concentrate diet as determined by individual milk production. The roughage (hay, silage) is self-fed. Thus, two methods of feeding are involved for dairy cows.
- Single animals, such as one beef steer, one pig, or one horse. This is the most practical method for individual feeding.

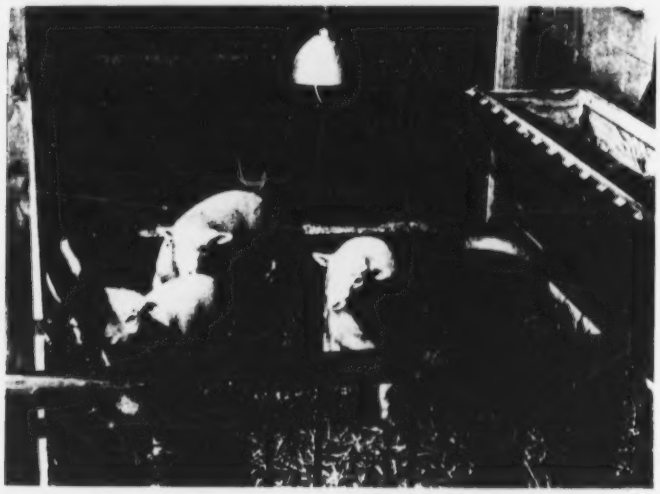

**Figure 96**

A clean, well-bedded creep for lambs. It provides grain, hay, and water and has a light to help attract lambs into it. The grain feeder should be covered, however, to keep lambs from getting their feet into it.
*(University of Illinois, Circular 1126)*



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## Self-Feeding

Figure 97

Self-feeding of swine *(John Deere)*

Livestock that are self-fed have feed before them at all times. Self-feeding involves special equipment that should be constructed so as to cut down on feed waste. The following livestock may be self-fed:

- Lambs, calves, foals, and pigs - creep feeding
  ***Creep feeding*** is providing a grain or pellet diet for nursing animals, or hay for lambs and calves (Figure 96). More rapid growth will result from creep feeding animals before they are weaned.
- Finishing hogs (weaning to marketing) (Figure 97)
- Finishing beef cows; (usually used where high quality roughage is the feed source)
- Dairy cows being fed roughage
- Finishing lambs

Self-feeding involves less labor than hand feeding. Self-feeding will be a success if:

- the feed supplies all required nutrients.
- the feed is palatable to the animals.
- the self-feeding equipment has room enough for all the animals.
- the equipment used does not permit waste of feed. Any waste of feed can be costly.

When animals are able to get all the feed they want, they will eat until satisfied. Weight gain and more production should be the result.

### *Free-Choice vs. Complete Feeds*

With free-choice feeding, the different parts of the diet, such as grain and protein concentrates with minerals and vitamins, are placed in separate compartments of a self-feeder. Then the livestock (usually pigs) are allowed to eat as much of each part of the diet as they want. They make their own choice in balancing the diet.

Free-choice feeding:

- ✣ is simpler for the livestock feeder.
- ✣ requires close supervision to be sure the livestock are eating a balanced diet.
- ✣ may result in overeating of the most costly part of the concentrate diet.
- ✣ may result in undereating of certain parts of the diet if either poor quality feed or feed with low palatability is provided.
- ✣ usually results in slower rate of gain.
- ✣ may cause poor feed efficiency.

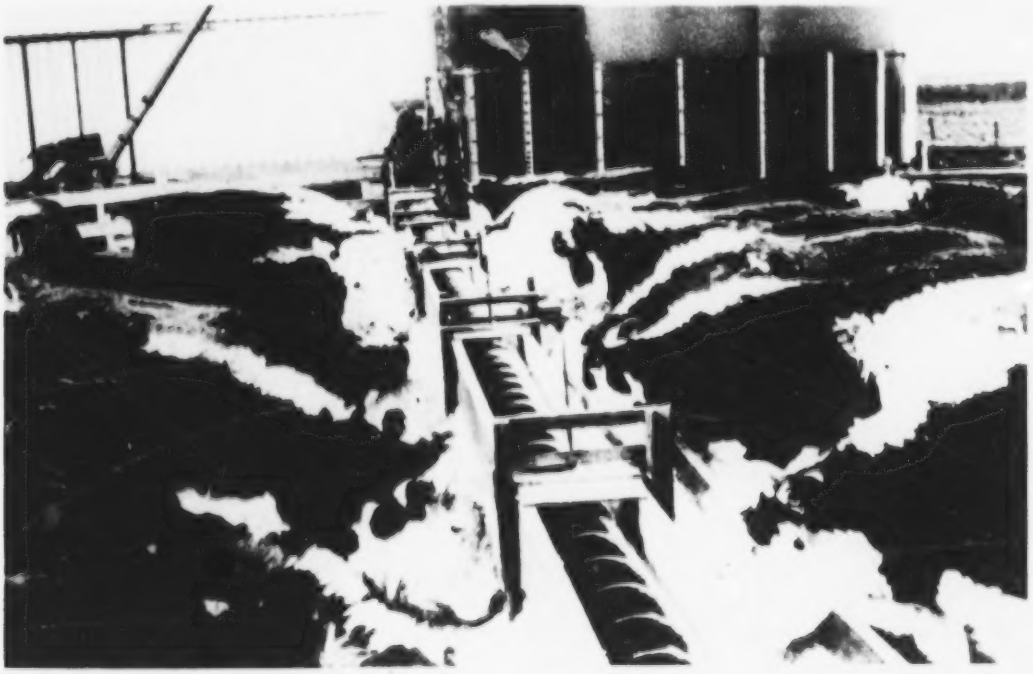
Complete mixed feeds are usually the most satisfactory for the livestock feeder. They are premixed with the proper balance of nutrients and are placed in self-feeders. In scientific literature, free access of animals to the feed is called ***ad libitum***.

## Automatic Feeding

There are several methods of feeding livestock automatically. One method is by mechanically-driven feeding equipment such as a combination of grain from a self-unloading silo, and grain and supplement from a discharge bin. The silage and grain are released in the correct proportions to provide a balanced diet. The feed is conveyed by a chain or auger to feed bunks (Figure 98). Because automatic feeding involves expensive equipment, only livestock feeders with large feeding operations are likely to use this system.

**Figure 98**

Automatic feeding of beef cattle. The feed is mixed by an auger. *(USDA Photo Service)*



Automatic feeding is used in feeding the following livestock:

- Finishing beef animals
- Beef brood cows and dairy cows; (with these animals silage may be the only feed fed automatically)
- Finishing lambs
- Poultry laying flocks
- Poultry broilers and turkeys
- Finishing hogs (weaning to marketing) (Figure 99)

**Figure 99**

Automatic feeding of swine
*(North Carolina State University)*

Several methods of automatic feeding used for dairy cattle are:

***Magnet-activated feeders.*** Cows wearing a magnetic device around their necks activate a mechanism which releases concentrates.

***Electronically-controlled feeding doors.*** These are on the feed bunk and are opened by cows wearing the activating device.

***Transponder feeders.*** The transponder is worn around the neck of the cow. It is set to control the amount of feed the cow receives (Figure 100). The

**Figure 100**

The cow is equipped with a transponder.

transponder system of automatic feeding controls the amount of feed a dairy cow gets based on her milk production. When the cow moves her neck into a loop-formed interrogator antenna to reach the feed (Figure 101), the transponder's code memory device electronically drives a signal generator. This causes feed to be dispensed slowly as the cow eats. When the memory device becomes fully charged, the dispenser stops and the cow gets no more feed.

***Computer-controlled concentrate feeder.*** Each cow wears an identifying device around her neck (Figure 102). As she approaches the feeder, her specific number is read electronically and the amount of feed she is programmed to receive is delivered (Figure 103). Some of these units can be connected to the home computer.

Farmers using computer-controlled feeders report:

- increased daily milk production of up to 2 pounds
- increased butterfat of up to 0.3 percent
- reduced concentrate feed cost of up to 30 percent
- improved animal health

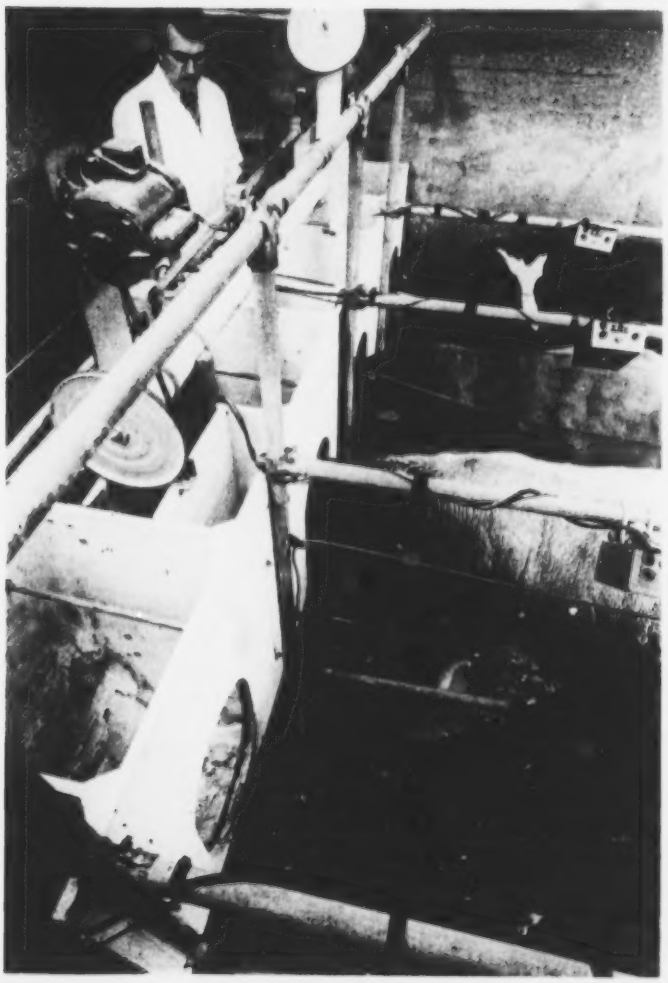


**Figure 101**

Cows having access to feed by the transponder system

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**Figure 102**

The cow wears an identification device that causes the specific amount of feed to be released when the cow enters the head box unit.

**Figure 103**

Computer-controlled feeder head-box units are usually located together.

Calculations indicate that while computer-controlled feeding devices are costly, they should pay for themselves in about 21/4 - 21/2 years.[1] Also, the management practices followed must be well above average if they are to prove successful.

## Mixing of Feedstuffs

Several methods of feeding livestock require mixing of the different feed ingredients. The energy- and protein-providing ingredients will be supplied in relatively large amounts. The mineral and vitamin premixes are supplied in relatively small amounts. This can present major problems in achieving an even distribution of each ingredient throughout the mixture.

Surveys of swine producers have shown that poor mixing of ingredients has resulted in diets that fail to meet nutritional requirements. This can happen even when adequate nutrients are provided. Farm mixing of feeds requires good equipment and a great deal of attention on the part of the operator.[2]

[1] For more information, consult the Ohio Dairy Guide, Leaflet DG 113, *Computerized Concentrate Feeders for Dairy Cows*, revised September 1988.

[2] Additional information about mixing feeds can be obtained from the Pork Industry Handbook leaflets, PIH 94 *Calibrating Meter-Type Feed Mills* and PIH 4 *On Farm Feed Processing*.

## GUIDELINES IN SELECTING DIETS

Livestock are fed under a wide range of conditions. Before a proper diet is selected, these feeding conditions must be identified. For example, dairy cattle fed free-choice alfalfa hay should be fed a concentrate diet that balances a high quality roughage. Animals receiving their roughage from a lower quality blue-grass pasture will need a different concentrate formulation.

The guidelines for selecting the proper diet are often referred to as "rules of thumb" because they are somewhat general in their recommendations. However, most of these guidelines are actually the result of extensive research by livestock nutritionists. In some situations, more should be fed than the guideline suggests. In other situations, less should be fed than the guideline suggests. The old livestock feeding saying, "The eye of the master fattens his cattle" may be appropriate to remember in feeding livestock. Guidelines should serve only as a starting point in selecting a diet. These guidelines are:

- ★ Trace mineral salt should be fed free choice.
- ★ The protein in concentrates should average 80 percent digestible.
- ★ Dry feeds contain about 90 percent dry matter. Hay contains about 80 to 85 percent dry matter.
- ★ Water in a clean, fresh condition should be provided free choice.

## FORMULATING AND BALANCING DIETS

As Figure 1 (page 2) shows graphically, from 50 to 75 percent of the cost of keeping an animal is tied up in feed. The exact percentage depends upon the class and use of the animal being fed.

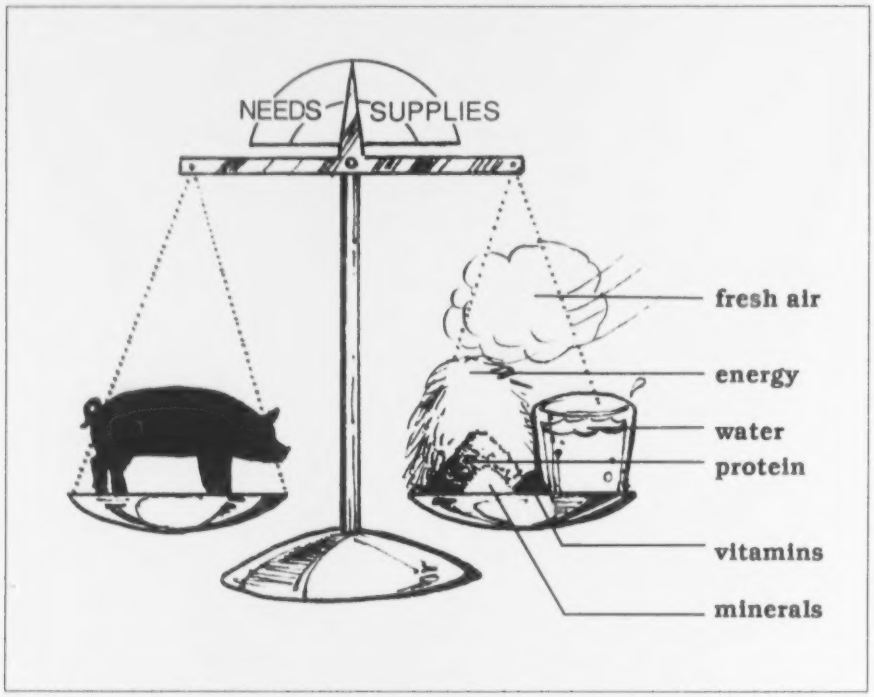
A balanced diet is one that provides, for a 24-hour period, all the nutrients needed (in the proper amounts and proportions) for the animal to perform the desired functions. In addition, the required nutrients must be contained in the amount of dry matter (DM) the animal is able to consume in a 24-hour period. Otherwise, the diet cannot be considered balanced (Figure 104).

Many different feeding situations exist in feeding farm animals. For example, a diet suitable for a dry, pregnant beef cow would be entirely unsuitable for a pregnant gilt. Thus, the livestock feeder must have a considerable knowledge of:

- ✣ the nature of the digestive tract of the animals being fed (Unit 1)
- ✣ the food nutrients required by animals (Unit 2)
- ✣ the nutrient requirements of livestock in each of their life cycle stages (Unit 3)
- ✣ the types of feedstuffs available and their composition (Unit 4)

**Figure 104**

When all the nutrient needs of an animal are supplied, the diet is balanced.

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The process of formulating and balancing diets is not difficult, but does involve several steps. First, you must know the nutritional needs of the livestock being fed. Next, you must know what feedstuffs are available to you and the nutrients each supplies. Much research has been conducted by animal scientists over the years to determine this information. You can consult textbooks on the subject, the local Cooperative Extension Service for appropriate publications, and the Ohio Agricultural Education Curriculum Materials Service for its instructional materials. From these sources you can obtain the information you need to balance the diets for your livestock.

You are well-advised to record the information about the nutrient needs of your livestock and the nutrients supplied by your feedstuffs. With the use of simple arithmetic, your feedstuffs can be proportioned into balanced diets for your livestock. Computer programs are also available to assist you in formulating balanced diets.

Other recommended information and materials that you should have on hand are:

- price lists of feed materials
  - farm price for farm-grown feeds
  - feed store price for other feeds, such as protein concentrates, supplements, and others. (Use feed store prices for farm-grown feeds if they are to be purchased.)
- guidelines for feeding livestock

- paper, pencil, and ruler
- worksheets for recording information, such as the following provided in this manual:
  - Worksheet A Feeds Available and Their Composition
  - Worksheet B Diet Evaluation
- hand calculator
- computer with appropriate software *(optional)*

## Methods of Balancing Diets

Four different methods may be used to balance livestock diets. The method is determined primarily by the number and kinds of feeds required. The four methods are:

- trial and error method
- square method
- square method with weighted averages
- algebraic methods

### *Trial and Error Method*

With the trial and error method, a diet is selected and nutrient contents are calculated. Then the nutrient content of the diet is checked against the livestock requirements. If the nutrient content and the livestock nutrient requirements balance, the diet is balanced. However, if one or more of the nutrients of the selected diet do not balance with the livestock nutrient requirements, the diet is in error. Thus, the amounts of certain feeds in the diet may need to be increased or decreased. Some feeds may need to be added or others eliminated from the diet. Hence the term "trial and error."

*Example:*

***Example***

A diet is needed for a 500-pound, medium-frame beef steer gaining 2.75 pounds per day. The following home-grown feeds are available:

alfalfa hay (sun-cured, early bloom)
corn silage (well-eared)
corn and cob meal
oat grain

44% soybean meal can be purchased.

The steps to follow are:

1. Determine the nutrient requirements of the animal.
2. Determine the amount of each feed to use.
3. Calculate the nutrient content of the feeds selected.
4. Through trial and error, adjust the amounts of feeds selected to meet the requirements of the animal, giving consideration to probable costs.

Using the guidelines for feeding beef cattle and the selection of suitable feeds that are available, you could select the following diet, with ***as-fed*** moisture content, for trial purposes:

10 lb corn silage (well-eared)
2 lb alfalfa hay (sun-cured, early bloom)
10 lb grain - 6 lb corn and cob meal
4 lb ground oats
1.5 lb soybean meal (44%)

**Table 31**

Comparison of nutrient requirements for a 500-pound beef steer and the nutrients supplied in a trial diet

| Feed Nutrients | Total Dry Matter | Crude Protein | NEM Mcal | NEG Mcal | Calcium lb | Phosphorus lb |
|---|---|---|---|---|---|---|
| ***Daily requirements*** (500 lb steer to gain 2-3 lb daily) | 13.0 | 1.63 | 10.27 | 6.63 | 0.073 | 0.040 |
| ***Amount in Diet*** | | | | | | |
| 10 lb corn silage | 3.3 | 0.270 | 2.38 | 1.45 | 0.008 | 0.007 |
| 2 lb alfalfa hay | 1.8 | 0.324 | 1.06 | 0.52 | 0.025 | 0.004 |
| 10 lb grain | | | | | | |
| 6 lb ground ear corn | 5.22 | 0.407 | 4.64 | 3.13 | 0.004 | 0.014 |
| 4 lb ground oats | 3.56 | 0.470 | 2.88 | 1.89 | 0.002 | 0.014 |
| 1.5 lb soybean meal | 1.33 | 0.660 | 1.21 | 0.81 | 0.004 | 0.009 |
| TOTAL | 15.21 | 2.131 | 12.17 | 7.80 | 0.043 | 0.048 |
| **Oversupply** | + 2.21 | + 0.501 | + 1.9 | + 1.17 | | + 0.008 |
| **Deficiency** | | | | | − 0.03 | |

Table 31 gives the nutrients required by the steer and the nutrients supplied by this diet.

The trial diet exceeds all nutrient requirements except calcium. There are many combinations that could be tried to reduce the oversupply of nutrients.

- Reduce the soybean meal to 0.5 pound.
- Substitute 4 pounds of corn and cob meal for the 4 pounds of oats, making the total corn 10 pounds.
- Increase the alfalfa hay to 3 pounds and reduce the corn silage to 6 pounds.

First try decreasing the soybean meal from 1.5 pounds to 0.5 pound. The row for soybean meal would then read as follows:

| Feed Nutrients | Total Dry Matter | Crude Protein | NEM Mcal | NEG Mcal | Calcium lb | Phosphorus lb |
|---|---|---|---|---|---|---|
| 0.5 lb soybean meal | 0.45 | 0.22 | 0.40 | 0.27 | 0.002 | 0.003 |
| TOTAL | 14.33 | 1.69 | 11.36 | 7.26 | 0.041 | 0.042 |
| **Oversupply** | + 1.33 | + 0.06 | + 1.09 | + 0.63 | | + 0.002 |
| **Deficiency** | | | | | − 0.032 | |

There is still a small oversupply of all nutrients except calcium. However, this change of diet is probably satisfactory, since it meets the minimum amounts for required energy and nutrients. The shortage of calcium can be corrected by feeding ground limestone.

## *The Square Method*

The square method is a convenient way to formulate simple diets. It can be used to formulate grain mixes or to determine the forage-to-concentrate ratio of complete feeds. The square method can be used to balance for any nutrient, but is most commonly used to balance for crude protein or energy. The following example illustrates how to determine the proportions of two feeds in a mix that is balanced for crude protein.

*Example:* ***Example***

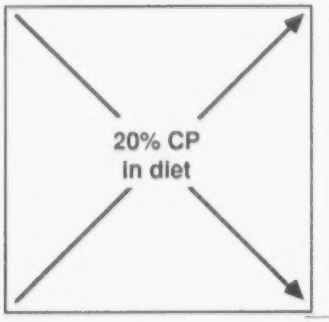
A diet will be formulated by using alfalfa hay as the roughage, and ear corn (10% CP) plus soybean meal (50% CP) as the concentrate. When alfalfa hay of average quality is used, the concentrate mix should contain 20% crude protein. The square method will be used to determine the proportions of ear corn and soybean meal needed to formulate a 20% mixed diet.

Before starting, try to answer this question: Will there be a greater proportion of ear corn or soybean meal in the final 20% mixture? Can you explain your answer?

***Procedure:***

1. Draw a square as shown below.
2. Place the percent crude protein desired in the center of the square, in this case, 20%.
3. In the upper left corner, place the crude protein percentage of the ear corn, which is 10.
4. In the lower left corner, place the crude protein percentage of the soybean meal, which is 50.
5. Subtract diagonally across the square. Place answers at the upper right and lower right corners. (Be sure to subtract the smaller number from the larger one.)
6. The answer at the upper right represents the parts or proportion of ear corn. The answer at the lower right represents the parts or proportion of soybean meal. Add the parts to determine the total.

*(continued)*




| Feeds | % CP | Parts | | Total Parts | | Percent | | Total Mix | | Amount of Each Feed to Use in Mix |
|---|---|---|---|---|---|---|---|---|---|---|
| ear corn | 10.0 | 30.0 | ÷ | 40.0 | = | .75 (75%) | x | 2000 lb | = | 1500 lb corn |
| soybean meal | 50.0 | 10.0 | ÷ | 40.0 | = | .25 (25%) | x | 2000 lb | = | 500 lb SBM |
| | | 40.0 total parts | | | | 100% | | | | 2000 lb. |

7. Convert the parts to percentages by dividing the individual feed part by the total parts. In this example, the diet would contain 75% ear corn and 25% soybean meal.
8. It is now easy to calculate the amount of ear corn and soybeans needed to make up a ton or half ton or 100-pound bag of 20% crude protein feed. Multiply the weight you need by the percent of the ingredient, e.g. 0.75 corn X 2000 lb = 1500 lb ear corn.

***Important points to remember:***

1. Always subtract diagonally across the square.
2. The value of one of the feed ingredients (in this case SBM is 50% CP) must be higher than the value of the desired mixture (20% CP). The value of the other feed ingredient (ear corn is 10%) must be lower than that of the desired mixture.
3. Each answer on the right represents a part of the feed item directly across from it, ***not*** diagonally from it.

## *The Square Method with Weighted Averages*

The square method with weighted averages is used when more than two different feedstuffs will be used in the total feed mixture.

***Example*** A concentrate diet containing 11% crude protein is needed. The grains to be used are ear corn and oats in this ratio: three parts ear corn to one part oats. Soybean meal and linseed meal will be used in equal amounts (half each) as the protein source. Calculate the average crude protein (CP) percentages of the grain and protein source mixtures.

1. Obtain the average CP% of each feed group.

| Low Protein Feed (Grains) | | High Protein Feed | | |
|---|---|---|---|---|
| 3 parts corn & cob meal | 9.0% CP | 1 part soybean meal | 49.9% | CP |
| + | 9.0% | + 1 part linseed meal | 25.0% | |
| | 9.0% | 2 parts | 74.9% | |
| 1 part oats | 13.4% | | | |
| 4 parts | 40.4% | | | |

40.4% ÷ 4 parts = 10.1% CP
Average CP of grain mix

74.9 ÷ 2 parts = 37.45% CP
Average CP of high protein feed mix

2. The proportions of grain and high protein feeds to be used in the concentrate mixture can now be determined using the square method, as shown below.

| Feeds | % CP | Parts | | Total Parts | | Percent | Total Mix | Amount to Use |
|---|---|---|---|---|---|---|---|---|
| corn & oats grain mix | 10.10 | 23.45 | ÷ | 27.35 | = | .8574 x (85.74%) | 2000 lb (1 ton) | = 1715 lb corn + oats |
| high protein mix | 37.45 | 3.9 | ÷ | 27.35 | = | .1426 x (14.26%) | 2000 lb (1 ton) | = 285 lb soybean + linseed meal |
| | | 27.35 total parts | | | | 100% | | 2000 lb |

3. Determine how much of each individual ingredient is needed.

| Feed | % of Grain Group | | Amount of Grain Group | | Total Amount to Use |
|---|---|---|---|---|---|
| corn & cob meal | .75 | x | 1715 lb | = | 1286 lb |
| oats | .25 | x | 1715 lb | = | 429 lb |

| Feed | % of Protein Group | | Amount of Protein Group | | Total Amount to Use |
|---|---|---|---|---|---|
| soybean meal | .50 | x | 285 lb | = | 142.5 lb |
| linseed meal | .50 | x | 285 lb | = | 142.5 lb |
| | | | | | 2000 lb total |

***Important note:*** The square method and square method with weighted averages can be used to balance for ***energy*** in the same manner that diets were balanced for ***crude protein.***

### *Algebraic Method-* With One Unknown

Another way of balancing a diet for crude protein, energy, or other nutrient is to use simple algebra. The algebraic method is used with the same formulation problems as the square method with the results being the same.

***Example*** A 20% CP diet must be formulated from ear corn (10% CP) and soybean meal (50% CP). What percentages of ear corn and soybean meal will the diet contain?

| What % of Feed 1 containing | + | What % of Feed 2 containing | do we need to mix together to equal | A 100% Total Diet |
|---|---|---|---|---|
| 10% CP | | 50% CP | = | 20% CP |

Before you attempt to put numbers into the formula, try to answer this question: Will there be a greater percentage of Feed 1 or Feed 2 in the final diet? Why?

***Formula***

| (amount of nutrient in Feed 1) | (amount of Feed 1 needed) | + | (amount of nutrient in Feed 2) | (amount of Feed 2 needed) | | total amount of nutrient in diet |
|---|---|---|---|---|---|---|
| (10% CP grain) | (x) | + | (50% SBM) | (y) | = | 20% CP in diet |

***Note:*** In order to solve for only one unknown, **y** can be changed to **x**.

If $x + y = 100\%$, then $y = 100\% - x$

$x + y = 100\%$

$-x + x + y = 100\% - x$

$y = 100\% - x$

$y = 1.0 - x$

$$
\begin{aligned}
.10x + .50y &= .20 \\
.10x + .50(1.0-x) &= .20 \\
.10x + .50 - .50x &= .20 \\
-.50 + .50 - .40x &= .20 - .50 \\
-.40x &= -.30 \\
\frac{-.40x}{-.40} &= \frac{-.30}{-.40}
\end{aligned}
$$

$x = .75 = 75\%$ grain

$y = 100 - 75$

$y = 25\%$ soybean meal

The 20% CP diet will contain 75% grain and 25% soybean meal. How many pounds of ear corn and soybean meal will be needed to mix one ton of mixed diet?

.75 grain X 2000 lb = 1500 lb grain
.25 grain X 2000 lb = 500 lb grain
2000 lb total mixed diet

It is always best to check your answer to see if it is correct. A simple mathematical error can cause a major nutritional problem. Check your answer by inserting the values you got for **x** and **y** into the original equation.

$$
\begin{aligned}
.10x + .50y &= .20 \\
(.10)(.75) + (.50)(.25) &= .20 \\
.075 + .125 &= .20 \\
.20 &= .20 \checkmark
\end{aligned}
$$

## *Algebraic Method-* With Two Unknowns- Simultaneous Equations

When mixed diets are being formulated, it is common to balance for more than one nutrient. A mixed diet must be balanced for protein, energy, minerals, and vitamins. One could use a series of square methods or algebraic methods. But a simpler and faster process is to use simultaneous algebraic equations. Simultaneous equations allow us to balance for two different nutrients at the same time without a lot of repetitive work. You will notice that the two formulas to be used are identical to those used in the algebraic method previously described.

| Ingredients | % DM | % CP | Mcal ME/lb |
|---|---|---|---|
| corn silage | 28 | 2.3 | 0.32 |
| soybean meal (SBM) | 90 | 49.0 | 1.24 |

*Example*

Balance a diet for a 450-pound growing steer requiring 1.2 pounds CP and 12.5 Mcal ME daily. Daily intake is estimated at 11 pounds DM.

| How many lb of Feed 1 containing | | How many lb of Feed 2 containing | do we need to mix together to equal | Pounds of Total Diet |
|---|---|---|---|---|
| 2.3% CP | + | 49% CP | = | 1.2 lb CP |
| 0.32 Mcal/lb | | 1.24 Mcal/lb | | 12.5 Mcal |

Before you attempt to put numbers into the equation, try to answer this question: Which do you expect to have in larger amounts in the diet: Feed 1 or Feed 2? Why?

*(continued)*

***Formula***

| | (amount of nutrient in Feed 1) | (amount of Feed 1 needed) | | (amount of nutrient in Feed 2) | (amount of Feed 2 needed) | | total amount of nutrient in diet |
|---|---|---|---|---|---|---|---|
| *For CP* | (2.3% CP silage) | (x) | + | (49.0% CP SBM) | (y) | = | 1.2 lb CP desired |
| *For energy* | (.32 Mcal) | (x) | + | (1.24 Mcal) | (y) | = | 12.5 Mcal desired |

**Solving for x:**

$$\begin{array}{rrrrr} 0.320\,x & + & 1.240\,y & = & 12.50 \\ -\,0.023\,x & + & 0.490\,y & = & 1.20 \end{array}$$

In order to solve for **x**, **y** must be deleted

$$\begin{array}{rrrrr} 0.32\,x & + & 1.24\,y & = & 12.50 \\ \times & & 0.49 & & \end{array}$$

$$0.16\,x + .61\,y = 6.13$$

$$\begin{array}{rrrrr} 0.23\,x & + & 0.490\,y & = & 1.20 \\ \times & & 1.24 & & \end{array}$$

$$0.029\,x + .61\,y = 1.49$$

These two steps are used to obtain similar **y** coefficients

$$\begin{array}{rrrrr} 0.160\,x & + & .61\,y & = & 6.13 \\ -\,0.029\,x & + & .61\,y & = & 1.49 \end{array}$$

$$0.13\,x = 4.64$$

Now that the **y** coefficients are equal, they can be eliminated from the equations.

$$.13\,x = 4.64$$
$$x = 4.64 \div 0.13$$
$$x = 35.69 \text{ lb of corn silage}$$

**Solving for y:**

$$.32\,x + 1.24\,y = 12.5$$
$$.32\,(35.69) + 1.24\,y = 12.5$$
$$11.42 + 1.24\,y = 12.5$$
$$-11.42 + 11.42 + 1.24\,y = 12.5 - 11.42$$
$$1.24\,y = 1.08$$
$$1.24\,y \div 1.24 = 1.08 \div 1.24$$
$$y = .87$$

***Checking calculations***

Here are the two original equations. Always check to make sure the answers are correct by inserting the values determined for x and y: (x = 35.69 y = 0.87).

| | | | |
|---|---|---|---|
| CP = | (0.023 x) | + (0.49 y) | = 1.2 |
| CP = | (0.023 x 35.69) | + (0.49 x 0.87) | = 1.2 |
| CP = | 0.82 | + 0.43 | = 1.2(5) |
| Mcal = | (0.32 x) | + (1.24 y) | = 12.5 |
| Mcal = | (0.32 x 35.69) | + (1.24 x 0.87) | = 12.5 |
| Mcal = | 11.42 | + 1.08 | = 12.5 |

***Important notes:***

- When using a calculator, use figures three places to the right of the decimal point. This will lessen the inaccuracies that occur in rounding off figures.
- The two equations can be arranged so that when subtraction is done, negative numbers will not result. Your answer will be the same either way, but it may be easier not to deal with negative numbers.
- Amount of nutrient can be expressed in percent, pounds, kilograms, or megacalories. Use whatever fits best in the particular situation.

## National Research Council Tables Introduced

The nutrients required for growth, maintenance, reproduction, and production of livestock are contained in the feeds we provide for them. The composition of these feeds and the nutrient requirements of livestock have been determined through extensive research by plant and animal scientists. The results have been compiled by the National Research Council (NRC) and published by the National Academy of Science in table form in a number of publications:

- ★ *United States-Canadian Tables of Feed Composition* (1982). Excerpts are included in Appendix Table 1C to give you information you will need to complete the illustrations and problems included in this chapter.

- ★ Nutrient requirement tables for the different species of livestock for different types and levels of activity. Only the tables actually used in this manual are included in the Appendix. They are:

  *Nutrient Requirements of Beef Cattle* (1984) - Excerpt Appendix Table 1 NR
  *Nutrient Requirements of Dairy Cattle* (1988) - Excerpt Appendix Table 2 NR
  *Nutrient Requirements of Horses* (1989) - Excerpt Appendix Table 3 NR
  *Nutrient Requirements of Sheep* (1985) - Excerpt Appendix Table 4 NR
  *Nutrient Requirements of Swine* (1988) - Excerpt Appendix Table 5 NR

The latter publications include tables of nutrient content of feeds as well as tables giving the nutrient requirements for each species of livestock. Check with your agricultural education instructor for reference copies of any of these manuals.

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A word of caution as you use the feed composition tables. . . When commercial feed manufacturers formulate a given feed, they adjust the ingredients to assure that the guaranteed analysis is achieved. There is ***no such guarantee*** for farm-grown feeds. The composition data published in the tables consist of ***averages*** of a great many analyses that have been made by scientists. The actual composition of your feedstuffs may be above or below the published data. How much the nutritive value of your feed varies from the published data will depend upon many factors such as kind of growing season, soil fertility level, and harvesting conditions. If you are unsure of the nutrient quality of your feeds, you may want to make use of a diet analysis service. (Your local Cooperative Extension Service office can advise you how to proceed.)

# Steps in Balancing Diets

There is no absolute procedure that must be followed in formulating balanced diets. The following steps may be used in the sequence given or in any order that works best for you.

*STEP 1*

**Identify the feedstuffs available to you for feeding your livestock.** These will include your farm-grown grains and roughages as well as the by-product concentrates you may purchase. List these feeds on **Worksheet A, *Feeds Available and Their Composition*** (page 172), in the *Feeds Available* column. The feeds listed on Worksheet A are the ones that will be used in all examples that follow. (A blank Worksheet A is included on page 177.)

*STEP 2*

**Determine the nutrient composition and energy values of each feedstuff identified in Step 1.** Record on Worksheet A. This information can be found by referring to Appendix Table 1C, ***Composition of Selected Feeds and Their Energy Values.***

When looking in the Composition Tables, you will notice that two line entries are given for each feed item. The figures in the upper row indicate nutrient content on an as-fed basis. The lower row figures are calulated on a dry matter basis.

*Example from Appendix Table 1C (page 10-A):*

| Soybean | | DM% | |
|---|---|---|---|
| 131 | Seeds, meal solv. extd. | 89 | = as-fed basis |
| 132 | | 100 | = dry (moisture-free) basis |

All columns except DM% should be recorded on a dry matter (100%) basis since most diets will be formulated on a dry basis.

- *DM%* column - Indicate the as-fed dry matter percentage in this row. These figures will be used at the end of calculations to transfer 100% dry matter figures into usable as-fed figures. When the feeds are finally mixed, the as-fed dry matter figures must be used to determine the actual weights of feeds needed.

- *Energy, Mcal/lb* column - Notice on the Composition Table that different energy values are given for the different types of livestock. In the Worksheet's *Energy Mcal/lb* column you need to list only the energy requirements for the type of livestock you will be feeding. For example:

  For producing dairy cows, use NEL.
  For growing dairy cattle and bulls, use NEG and NEM.
  For growing and finishing beef cattle, use NEG and NEM.
  For breeding beef cattle, use NEG and NEM.
  For sheep and swine, use ME.
  For horses, use DE.

## Worksheet A Feeds Available and Their Composition (dry basis - moisture free)

Date 3/23/92 Prepared by *John Miller*

| Feeds available | DM % as-fed | Energy Mcal/lb* | | | | CP % | Ca % | P % | Lysine for Swine % | Other Vitamins | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NEM | NEG | NEL | ME | | | | | A | B |
| *Alfalfa hay (sun-cured, early bloom)* | 90 | 0.59 | 0.29 | 0.61 | 1.01 | 18.0 | 1.41 | 0.22 | 0.90 | | |
| *Corn silage (well-eared)* | 33 | 0.73 | 0.44 | 0.73 | 1.21 | 8.1 | 0.23 | 0.22 | 0.43 | | |
| *Red clover hay (sun-cured)* | 89 | 0.54 | 0.21 | 0.56 | 0.90+ | 16.0 | 1.53 | 0.25 | NA | | |
| *Timothy hay (sun-cured, full bloom)* | 89 | 0.57 | 0.26 | 0.59 | 0.81+ | 8.1 | 0.43 | 0.20 | NA | | |
| *Corn ears (gr.) (corn & cob meal)* | 87 | 0.89 | 0.60 | 0.87 | 1.47 | 9.0 | 0.07 | 0.27 | 0.20 | | |
| *Corn grain* | 89 | 0.95 | 0.64 | 0.91 | 1.55 | 10.9 | 0.03 | 0.29 | 0.28 | | |
| *Soybean meal (sol. ext. 44%)* | 89 | 0.91 | 0.61 | 0.88 | 1.49 | 49.9 | 0.34 | 0.70 | 2.99 | | |
| *Oat grain* | 89 | 0.81 | 0.53 | 0.80 | 1.45+ | 13.3 | 0.07 | 0.38 | 0.44 | | |
| *Barley grain* | 88 | 0.91 | 0.61 | 0.88 | 1.49 | 13.5 | 0.05 | 0.38 | 0.44 | | |
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* Use the appropriate energy designation for the livestock to be fed. + Digestible energy (DE) figures are used in feeding horses

- *CP%, Ca%,* and *P%* columns - The percentages can be transferred direct from Appendix Table 1C to Worksheet A.

- *Lysine for Swine and Horses* column - Lysine is the most critical amino acid in swine diets and is important in horse diets too. For this reason swine diets must be formulated so that they provide adequate lysine. The percentages for lysine are listed as a percent of dry matter.

- *Other* column - This space is provided for listing other critical nutrients that are not listed on the worksheet, such as individual vitamins and other minerals.

Completing Worksheet A will familiarize you with the different feedstuffs. Also, you will not have to go to the larger Composition Tables every time you need data for a feedstuff. If you have had your feed analyzed for energy and nutrient content, record the data from that analysis on your Worksheet A.

***STEP 3***

**Identify life cycle stage information for the animals being fed.** (See Unit 3.) Record the necessary information at the top of Worksheet B, ***Diet Evaluation.*** (See page 178.) You may have to identify such information as:

weight of the animal
body conformation (when applicable)
    small frame
    medium frame
    large frame
rate of gain desired (when applicable)
milk production
    dairy cows - pounds of milk per day and butterfat test
    beef cattle - light, medium, or heavy production
stage of gestation

***STEP 4***

**Identify the total dry matter intake and the nutrient and energy requirements for the livestock being fed.** Record this information in the first row of Worksheet B. This information can be obtained from the nutrient requirement tables in the Appendix. Your state Cooperative Extension Service may have published nutrient requirement tables that give higher recommendations than those given here. If so, follow the recommendations of the Cooperative Extension Service.

***Important points*** to remember when using the Nutrient Requirement Tables:

- Be careful of the ***basis*** used in the various nutrient tables. Many nonruminant tables show percentages on ***as-fed basis***. Tables for ruminants commonly use a ***dry matter basis***. The two sets of data cannot be compared and should not be used together without first making a conversion to the same basis.

**Table 32**
Weight Equivalents

1 lb = 453.6 g = 0.4536 kg
1 oz = 28.35 g
1 kg = 1,000 g = 2.2046 lb
1 g = 1,000 mg
1 mg = 1,000 µg = 0.001 g
1 µg = 0.001 mg = 0.000001 g
1 µg per g or 1 mg per kg is the same as ppm

- Nutritional requirements are often stated as a ***proportion*** of the diet instead of as a ***percentage*** of the diet when diets are fed ad libitum (free access to feed). This is often the case with swine.
- Both metric and avoirdupois measurements are used in the Appendix tables. Be careful not to mix these measurements together when recording data. Table 32 should be helpful, along with a calculator, in making conversions from one system to another. (Also see the last Appendix table for more conversion factors.)

*STEP 5*

**Identify feeding guidelines that are appropriate for your livestock.**
These guidelines are not accurate enough to use in formulating balanced diets. However, they can be used as a starting point in determining the amounts of each ingredient to use. For example, here are several guidelines for feeding dairy cattle:

- Lactating cows should be fed 3.5 percent of their body weight in dry matter.
- Roughage should be limited to 1.75 percent of body weight in dry matter.
- Half the forage dry matter will be fed as alfalfa hay and half as corn silage.

*STEP 6*

**Formulate and evaluate the diet using Worksheet B. *Diet Evaluation.***
To start, an initial mix of feeds can usually be established by referring to the feeding guidelines. You will then need to determine the nutrient content of the feeds to be used and whether a nutrient oversupply or undersupply exists. As you progress through the formulation process, the amount of individual feed ingredients may need to be adjusted. This will affect the level of particular nutrients in the diet. Energy or protein will be the first nutrient to balance for. Which method of calculation will you use - trial and error, the square methods, or the algebraic methods? That will depend on the complexity of your diet and how confident you are using the different mathematical procedures.

Always check your work to see if the answers you receive are reasonable. Some common mistakes include simple errors in arithmetic, misplaced decimal points, data taken from the wrong place on a table, and copying numbers inaccurately. There is a big difference, for example, between 1.4% and 14%. Even such 'simple' errors can have a major impact on the composition of the final diet. A diet based on errors could seriously affect your animals' health and level of production.

**Important biological concepts to learn from Unit 5:**

- ★ Feed from a properly balanced diet that is wasted by an animal will result in its being underfed.
- ★ The ingredients of a diet must be completely mixed to enable the animal to consume the intended balanced diet. Improperly mixed ingredients cause the animal to consume too much of one ingredient and too little of others.
- ★ The energy and nutrients required by an animal in a balanced diet must be included in an amount of feed that the animal can reasonably be expected to consume in one day.

## REVIEW of Unit 5

After studying Unit 5, "Methods and Procedures for Determining Nutrient Requirements and Selecting Balanced Diets," you should be able to answer and discuss the following.

1. What factors must be considered in determining the method of feeding to follow in feeding your livestock? *(page 153)*
2. What methods of feeding are available to the livestock feeder? *(page 153)*
3. Describe the differences between free-choice feeding and feeding of a completely mixed feed. *(pages 154-155)*
4. Describe the different types of automatic feeding devices that are available to livestock producers. *(pages 155-158)*
5. Why is it so important that the various ingredients of a feed mixture be thoroughly mixed together? *(page 158)*
6. Since feeding guidelines are not accurate enough to follow in formulating a balanced diet, how can you best use them in your approach to formulating balanced diets for your livestock? *(page 159)*
7. What are the four mathematical methods that can be used in formulating balanced diets? *(page 161)*
8. In following the trial and error method of balancing an animal's diet, what is your main source of information in determining the proportions of each ingredient to include in your first trial diet? *(pages 161-162)*
9. Using the square method, determine the proportions of a grain mixture containing 11% CP and a protein concentrate mixture containing 38% CP when a complete mixture containing 15% CP is desired. *(page 163)*
10. Using the square method with weighted averages, determine the proportions of forage mix to concentrate mix to feed to obtain a diet supplying 0.802 ME Mcal per pound of DM in the diet. The feedstuffs are as follows: *(pages 164-165)*

    *Forages*

    | | |
    |---|---|
    | Hay | 1 part DM containing 0.58 ME Mcal/lb DM |
    | Silage | 1 part DM containing 0.74 ME Mcal/lb DM |

    *Concentrate*

    | | |
    |---|---|
    | Corn & cob meal | 8 parts DM containing 0.86 ME Mcal/lb DM |
    | Soybean meal | 1 part DM containing 0.89 ME Mcal/lb DM |

11. Using an algebraic equation, determine the proportion of grain to concentrate to use in formulating a diet that is to contain 17% CP when: *(page 166)*
    the grain mixture contains 9% CP, and
    the protein concentrate contains 52% CP.
12. Using a simultaneous equation, determine the proportions of alfalfa hay to soybean meal to use in supplying an animal with 1.5 lb CP and 14.0 ME Mcal daily. The feedstuffs are as follows: *(pages 167-168)*

| Ingredient | % DM | % CP | ME Mcal/lb |
|---|---|---|---|
| alfalfa hay | 90 | 17 | 0.99 |
| soybean meal | 89 | 48 | 1.26 |

13. What are the limitations of nutrient requirement tables? *(page 170)*

## Worksheet A Feeds Available and Their Composition (dry basis - moisture free)

Date _____ Prepared by _____

| Feeds available | As fed lb | DM % | Energy Mcal/lb* | | | | CP % | Ca % | P % | Lysine for Swine % | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NEM | NEG | NEL | ME | | | | | | |
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* Use the appropriate energy designation for the livestock to be fed.

## Worksheet B Diet Evaluation

Date _____ Prepared by _____ Species _____ Weight _____

Type of animal or use _____ Special considerations _____

| | As fed lb | DM lb | Energy Mcal* | | | | For swine change lb to % | | | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NEM | NEG | NEL | ME | CP lb | Ca lb | P lb | Lysine for Swine lb | | |
| Daily nutrient requirements | | | | | | | | | | | | |
| Feedstuffs in diet | | | | | | | | | | | | |
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| | | | | | | | | | | | | |
| Total in diet | | | | | | | | | | | | |
| Oversupply | | | | | | | | | | | | |
| Undersupply | | | | | | | | | | | | |

* Use the appropriate energy designation for the livestock to be fed.

UNIT 6

# FEEDING GUIDELINES AND EXAMPLE DIET FORMULATIONS

## APPLIED ACADEMIC AREAS

**Mathematics**

- Employ data analysis - read and interpret graphs, tables, charts
- Use addition, subtraction, multiplication, and division of decimal numbers
- Use equivalent fractions, decimals and percents
- Determine percentage, rate and base
- Solve linear equations
- Solve systems of linear equations in two variables

**Terms to know**

antibody
colostrum
compensating
foaling
freshening
milk replacer
postpartum
weanling

## INTRODUCTION

You have now learned what methods are used for feeding livestock. You have been given guidelines for selecting diets and methods for balancing them. You have discovered how to find the composition of various feedstuffs and how to use the NRC nutrient requirement tables. To illustrate how balanced diets can be formulated, one sample diet for each species has been prepared and is included in this chapter. You can now get help in formulating a diet for the animal(s) you plan to raise.

As a result of studying Unit 6, you should be able to do the following:

1. Determine the nutrient requirements of the livestock you are raising.
2. Use the guidelines suggested as they apply to the livestock you are raising.
3. Calculate a balanced diet for each livestock species as determined by:
   - classification - ruminant or nonruminant
   - age
   - weight
   - production - milk, wool, or work, and average daily weight gain desired
   - reproduction - nursing young and stage of gestation

# BEEF CATTLE

## GUIDELINES FOR FEEDING BEEF CATTLE

Cattle should always be fed according to class and individual needs.

## Beef Cow Herd Feeding

### *Summer Pasture Feeding*

Pasture will supply most of the nutrients needed. A mineral mixture such as the following should be fed free-choice: 1 part steamed bone meal, 1 part trace mineral salt, and 1 part dicalcium phosphate. Salt may be fed free-choice.

If the pasture is short or inadequate and corn silage is available:

- 15 pounds of corn silage per head per day will substitute for one-third of the pasture acreage.
- 30 pounds of corn silage will make up for two-thirds of the pasture acreage.
- 5 pounds of good quality hay will give the same results as 15 pounds of corn silage.
- 10 pounds of good quality hay will give the same results as 30 pounds of corn silage.

### *Winter Feeding*

The quality and amount of roughage fed determines the kind and amount of concentrate to feed.

During gestation the cow must be fed adequately to produce a strong calf. The dry feed requirements of winter-fed beef cows (dry, pregnant) are calculated according to the condition of the cows and the percentage of body weight as shown in Table 33.

Table 33

Dry feed needs of pregnant cows

| Condition of Dry, Pregnant Cow | Dry Feed Needs- Percent of Body Weight |
|---|---|
| Thin | 2.25% |
| Average flesh | 2.00 |
| Good condition | 1.75 |

Table 34

Dry feed needs of nursing cows

| Condition of Cow Nursing | Dry Feed Needs- Percent of Body Weight |
|---|---|
| Thin | 3.375% |
| Average flesh | 3.0 |
| Good condition | 2.625 |

Cows nursing calves must be provided with enough nutrients to produce milk and to maintain their own bodies (Figure 105). They require 50 percent more dry feed than dry cows do (Table 34).

Hay may be replaced by silage.

**Figure 105**

Cow with a nursing calf

## Market Cattle Feeding

### *Dry Lot Feeding*

Cattle on full feed will eat about 3 percent of their live weight in air-dried roughage per day. Silages must be converted to their hay equivalent. (See Table 36, page 188.) Cattle on maintenance diets will need about 2 percent of their live weight in air-dried roughage per day. The amount of corn silage fed should be limited or the cattle fed poorer quality roughages.

Well-eared, mature corn silage is the top producer of beef per acre, but it does not have enough energy to fatten young cattle at light weights. In feedlots, 15 percent roughage and 80 percent concentrate are fed to finish cattle to market weight.

High-quality hay fed to cattle on grain will result in as much as 20 to 30 percent higher dry matter intake when compared to late-cut, weather-damaged hay. Low-quality hay lacks palatability and nutrients and requires more time to pass through the digestive tract.

### *Pasture Feeding*

Many people grow cattle from weaning to 700-800 pounds on pasture and then sell the cattle to a feedlot.

# NUTRIENT REQUIREMENT TABLE FOR BEEF CATTLE

The table we will use to determine the energy and nutrient requirements of an example beef cattle diet is:

**Appendix Table 1 NR** ***Nutrient Requirements for Growing and Finishing Cattle***

This table separates the growing and finishing cattle as to sex (heifer, bull, steer) and frame size (medium frame and large frame) into the following categories:

- Medium-frame steer calves
- Large-frame steer calves and compensating medium-frame yearling steers
- Medium-frame bulls
- Large-frame bull calves and compensating large-frame yearling steers
- Medium-frame heifer calves
- Large-frame heifer calves and compensating medium-frame yearling heifers

# EXAMPLE DIET FOR BEEF CATTLE **For Growing and Finishing Cattle**

The following example will illustrate how to formulate a balanced diet for a 600-pound, medium-frame steer calf. The steer calf will be expected to gain an average of 2.0 pounds per day.

The six steps outlined in Chapter 5 (pages 171-174) can now be used to formulate a balanced diet for this example steer calf.

*STEP 1* **Identify the feedstuffs that are available for feeding to the example steer calf.** Plan to feed a high roughage diet. For this exercise the following feedstuffs will be used:

corn silage (well-eared)
soybean meal (sol. ext. 44%) if needed to supply additional protein

*STEP 2* **Determine the nutrient composition and energy values of each feedstuff identified in Step 1.** Refer to **Worksheet A,** ***Feeds Available and Their Composition*** (page 172). Worksheet A contains information that we will use throughout Chapter 6, taken from **Appendix Table 1C,** ***Composition of Selected Feeds and Their Energy Values.***

*STEP 3* **Identify the steer's life cycle stage information.** Refer to **Worksheet B, Sample 1** (page 183). At the top is the necessary information for the example steer for which the diet is being formulated.

## Worksheet B, Sample 1 Diet Evaluation

Date 3/31/92 Prepared by John Doe Species Beef Weight 600 lb

Type of animal or use Growing - finishing steer calf Special considerations Gaining 2.0 lb/day Medium frame

| | As fed lb | DM lb | Energy Mcal*/lb | | | | CP % | Ca % | P % | Lysine for Swine | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NEM | NEG | NEL | ME | | | | | | |
| Daily nutrient requirements | | 15.0 | 0.70 | 0.44 | | | 10.5 | 0.40 | 0.22 | | | |
| Feedstuffs in diet | | | | | | | | | | | | |
| *Corn silage - well-eared* | | | | | | | | | | | | |
| *Maintenance* | | | 0.686 | | | | | | | | | |
| *Gain* | | | | 0.414 | | | | | | | | |
| *Total* | 42.7 | 14.1 | | | | | 7.6 | 0.22 | 0.21 | | | |
| *Soybean meal (44% CP)* | | | | | | | | | | | | |
| *Maintenance* | | | 0.055 | | | | | | | | | |
| *Gain* | | | | 0.037 | | | | | | | | |
| *Total* | 1.0 | 0.9 | | | | | 3.0 | 0.02 | 0.04 | | | |
| *Trace mineral salt* / *Limestone* | *mixture fed free choice or topdressed* | | | | | | | | | | | |
| Total in diet | 43.7 | 15.0 | 0.741 | 0.451 | | | 10.6 | 0.24 | 0.25 | | | |
| Oversupply | | - - | 0.041 | 0.011 | | | 0.01 | | 0.03 | | | |
| Undersupply | | - - | | | | | | 0.16 | | | | |

* Use the appropriate energy designation for the livestock to be fed

***STEP 4*** **Identify the dry matter intake and the energy and nutrient requirements for the steer calf.** This information, shown here from Appendix Table 1 NR, is recorded on Worksheet B, Sample 1.

| Weight (lb) | Daily Gain (lb) | Dry Matter Intake (lb) | Protein (%) | NEM (Mcal/lb) | NEG (Mcal/lb) | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|
| | | | *Medium-frame steer calves* | | | | |
| 600 | 0.5 | 13.2 | 8.2 | 0.50 | 0.25 | 0.23 | 0.18 |
| | 1.0 | 14.1 | 9.0 | 0.57 | 0.31 | 0.28 | 0.19 |
| | 1.5 | 14.7 | 9.8 | 0.64 | 0.38 | 0.35 | 0.21 |
| → | 2.0 | 15.0 | 10.5 | 0.70 | 0.44 | 0.40 | 0.22 |
| | 2.5 | 14.9 | 11.4 | 0.79 | 0.51 | 0.46 | 0.24 |
| | 3.0 | 13.5 | 12.9 | 0.95 | 0.64 | 0.57 | 0.29 |

***STEP 5*** **Balance for both NEM and NEG.** Both must be balanced when formulating diets for growing beef cattle. It is not possible to use one net energy figure to balance accurately for needed energy.

***STEP 6*** **Formulate the diet.** The steps to be used in balancing this diet are as follows:

**A.** Balance the diet for protein using the square method.
**B.** Calculate the nutrients provided by each feed.
**C.** Calculate the total nutrients provided by the diet.
**D.** Identify any deficiencies.
**E.** Determine the pounds of each feed to use.

**A.** Using the square method, balance a 10.5% crude protein diet with corn silage and soybean oil meal.

| Feed | % CP | | Parts | | Total Parts | | Percent of Each Feed to Use in Mix | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| corn silage | 8.1 | | 39.4 | + | 41.8 | = | 0.94 x 100 | = | 94 % |
| | | 10.5 | | | | | | | |
| SBM | 49.9 | | + 2.4 | + | 41.8 | = | 0.06 x 100 | = | 6 % |
| | | Total | 41.8 | | | | | | 100 % |

(B.) Calculate the nutrients provided in a diet composed of 94% corn silage and 6% SBM.

| | NEM Mcal/lb | NEG Mcal/lb | CP % | Ca % | P % |
|---|---|---|---|---|---|
| corn silage | 0.73 Mcal/lb | 0.44 Mcal/lb | 8.1 % | 0.23 % | 0.22 % |
| | 0.73 Mcal | 0.44 Mcal | 0.081 | 0.0023 | 0.0022 |
| | x .94 | x .94 | x .94 | x .94 | x .94 |
| | 0.686 Mcal | 0.414 Mcal | 0.076 | 0.0022 | 0.0021 |
| | | | or | or | or |
| | | | 7.6% | 0.22% | 0.21% |

| | NEM Mcal/lb | NEG Mcal/lb | CP % | Ca % | P % |
|---|---|---|---|---|---|
| SBM | 0.91 Mcal/lb | 0.61 Mcal/lb | 49.9 % | 0.34 % | 0.70 % |
| | 0.91 Mcal | 0.61 Mcal | 0.499 | 0.0034 | 0.007 |
| | x 0.06 | x 0.06 | x 0.06 | x 0.06 | x 0.06 |
| | 0.055 Mcal | 0.037 Mcal | 0.030 | 0.0002 | 0.0004 |
| | | | or | or | or |
| | | | 3.0% | 0.02% | 0.04% |

(C.) Calculate the total nutrients provided.

| | NEM Mcal/lb | NEG Mcal/lb | CP % | Ca % | P % |
|---|---|---|---|---|---|
| corn silage | 0.686 Mcal | 0.414 Mcal | 7.6% | 0.22% | 0.21% |
| SBM | + 0.055 Mcal | + 0.037 Mcal | + 3.0% | + 0.02% | + 0.04% |
| Total nutrients provided | 0.741 Mcal | 0.451 Mcal | 10.6% | 0.24% | 0.25% |

(D.) Determine whether any nutrients are deficient.

| | NEM Mcal/lb | NEG Mcal/lb | CP % | Ca % | P % |
|---|---|---|---|---|---|
| Nutrients provided | 0.741 | 0.451 | 10.6 | 0.24 | 0.25 |
| Nutrients required | − 0.70 | − 0.44 | − 10.5 | − 0.40 | − 0.22 |
| | + 0.041Mcal | + 0.011Mcal | + 0.1% | − 0.16% | + 0.03% |

All nutrients except for calcium have been provided at the recommended amounts. Free-choice trace mineralized salt with added limestone should take care of the calcium deficiency. To make certain that the animal consumes the amount of calcium required, the mineral mix could be topdressed onto the feed.

(E.) Determine the pounds of each feed to use when mixing the diet for the 600-pound steer.

1 ) Calculate the pounds of each feed on a dry matter basis. We know the steer can consume 15 pounds DM daily.

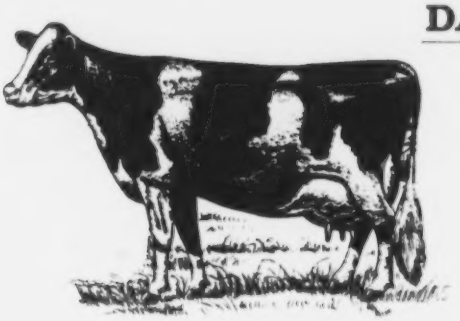
94% **corn silage** x 15 lb DM = 14.1 lb CS as dry matter

6% **SBM** x 15 lb DM = 0.9 lb SBM as dry matter

15.0 lb total mix

2 ) Now calculate the as-fed weight for each feed item.

| | pounds | | % moisture as-fed | |
|---|---|---|---|---|
| **corn silage** | 14.1 lb | ÷ | 0.33 | = 42.7 lb CS |
| **SBM** | 0.9 lb | ÷ | 0.89 | = 1.0 lb SBM |
| | | | | 43.7 **total lb of feed as-fed** |



# GUIDELINES FOR FEEDING DAIRY CATTLE

## Lactating Cows and Roughage

Lactating cows should be fed about 3.5 percent of their body weight (in DM), but the percentage will vary depending on the level of milk production. The estimated daily intake of roughage amounts is affected by the quality of the roughage fed. See Table 35 for a guide to estimating the free-choice consumption of hay when quality varies from excellent to poor.

If cows are allowed to consume all the roughage they can, they may not have the capacity to consume enough concentrates to meet the energy requirements of high milk production. (See Figure 106.) Thus, setting a maximum roughage consumption level is often a good idea. In some states, the Dairy Herd Improvement Association (DHIA) uses 1.75 percent of body weight as the maximum amount allowed.

**Table 35**

Recommended daily intake of roughage according to its quality

| Roughage Quality | Daily Intake (% of body weight on a dry matter basis) |
|---|---|
| Excellent | 3.0 |
| Good | 2.5 |
| Average | 2.0 |
| Fair | 1.5 |
| Poor | 1.0 |

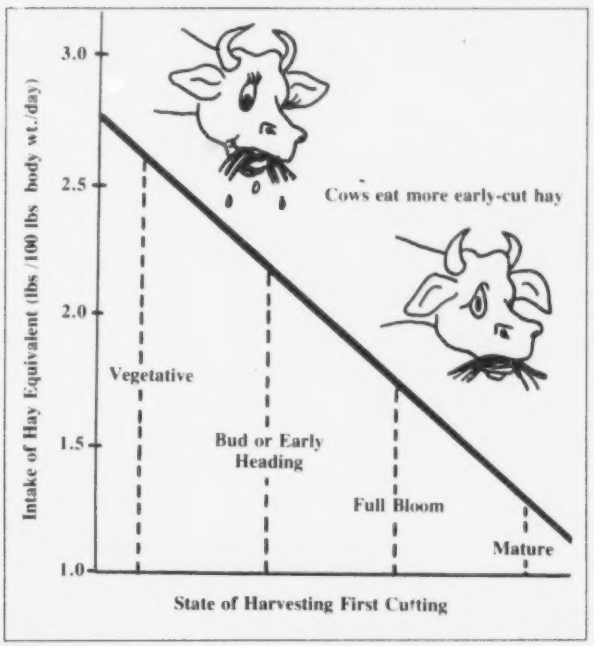



**Figure 106**

Cows eat more early-cut hay, which is higher in nutrients per ton than is late-cut hay, so less concentrate feed is required. *(Raymaley, F.A., and Baylor, J.E.,* Put Up High Energy Hay, 24 Ways to Make Forage Pay, *American Grassland Council, Leola, PA, p.37)*

## Silage

When silages, which are high in moisture content, are fed to livestock, one must know what percent dry matter the animal is actually receiving. Also, if hay is being fed, how much silage is needed to replace it in the diet? A rule of thumb when feeding silage is to keep the dry matter percentage to less than 50 percent. Hay equivalent charts can also be helpful in determining the amount of silage to feed (Table 36). ***Hay equivalents*** are the pounds of silage needed to replace the dry matter available in hay.

*Example* The hay equivalent of 18 pounds of corn silage is 18 ÷ 3, or 6 pounds hay equivalent.

If a cow is consuming 14 pounds of hay per day, half of the hay can be replaced with 14 pounds of haylage.

(7 lb hay to be replaced x 2 hay equivalent value = 14 lb haylage)

---

**Table 36**

Conversion of high moisture forages to hay equivalents

| Kind of Forage | % DM | Hay Equivalent = Pounds of Forage ÷ |
|---|---|---|
| Hay | 90 | 1 |
| Haylage | 45 | 2 |
| Corn silage | 30 | 3 |
| Wilted legume grass silage | 30 | 3 |
| Direct cut legume grass silage | 22 | 4 |
| Green chop | 18 | 5 |

*Source: Ohio Cooperative Extension Service,* Dairy Guide, *Leaflet DG 105*

---

## Concentrates

The concentrate mixture of feeds will vary with the kind of roughage fed. A higher protein concentrate mixture will be required when a low quality roughage is fed. The amount of concentrate in the total diet should not exceed 55 percent of the total dry matter intake (DMI). Typically, 50 percent concentrate is fed to early lactating cows to prevent milk fat depression.

Concentrates are fed to provide the nutrients that are not provided by roughage. Based upon average intake of average quality hay, the traditional rules of thumb for concentrate feeding are:

- One pound of concentrate for every three pounds of milk produced by high-testing breeds (4.5 to 5.5% butterfat); and/or
- One pound of concentrate for every four pounds of milk produced by low-testing breeds (3 to 4.5% butterfat).

These recommendations work very well for high-testing cows producing about 30 pounds of milk and low-testing cows producing 35 to 40 pounds of milk. Thus, **high-producing cows are underfed and low-producing cows are overfed.**

More specific guidelines to follow for concentrate feeding are:

- The concentrate should provide no more than 60 percent of the total dry matter of the diet.
- The concentrate intake should account for no more than 2.3 percent of the animal's body weight per day.

Table 37 can be used as a guide for feeding grain concentrates according to milk production.

The protein percentage, crude or digestible (whichever value is used), should be adjusted according to the kind and quality of roughage fed. Table 38 gives suggested percentages of digestible protein in concentrate diets with the different qualities of roughage fed.

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**Table 37**

Amount of concentrate (grain) to feed by periods (1,4000-lb cow, 4% milk)

*(Adapted from Linn, J.G., et al., Feeding the Dairy Herd, Cooperative Extension Services, Universities of Illinois, Iowa State, Minnesota, and Wisconsin, 1988, p. 26, Table 18)*

| | Milk Production Ability of the Cow* | | | |
|---|---|---|---|---|
| **Average daily first period** (lb) | 50 | 60 | 80 | 90-100 |
| **Lactation total** (lb) | 10,000 | 12,000 | 15,000 | 18,000 |
| **Phase of Lactation** | **Grain to Milk Ratio** | | | |
| 1 (1st 10 weeks) | 1:4 | 1:3 | 1:3 | 1:2.5 |
| 2 (2nd 10 weeks) | 1:4 | 1:3 | 1:3 | 1:3 |
| 3 (last 24 weeks) | 1:4 | 1:4 | 1:2.5 | 1:2.5 |
| | Daily | Daily | Daily | Daily |
| 4 (dry, 6-8 weeks) lb | 0-4 | 0-4 | 0-4 | 0-6 |
| **Total grain** lb (approximate) | 3,000 | 4,000 | 5,000 | 6,000 |

* Ratios based on 100% dry matter basis, grain containing 80 Mcal, and forage 60 Mcal of NEL per 100 lb (45 kg)

**Table 38**

Approximate digestible protein percentage needed in concentrate mixture with different quality forages

| Kind of Forage | Quality of Forage | | |
|---|---|---|---|
| | *Excellent* | *Average* | *Poor* |
| Legume hay or silage | 10% | 11% | 12% |
| Mixed legume-grass hay or silage | 13 | 14 | 15 |
| Non-legume grass | 16 | 17 | 18 |
| Corn silage | 19 | -- | -- |
| Urea-treated corn silage | 14 | -- | -- |

*Source: Ohio Cooperative Extension Service,* Dairy Guide, *Leaflet DG 105*

Table 39

Approximate digestible protein percentage needed in concentrate mixture with different quality pastures

| Quality of Pasture | Percent Digestible Protein in Concentrate Mixture |
|---|---|
| Excellent, young, green pasture | 8-9 |
| Grass-legume pasture-grass near ripening | 12-14 |
| Coarse grass legume, grasses | 12-13 |
| Fully ripened grass pasture | 14-15 |

## Pasture

For dairy cows on good quality pasture, feed two-thirds as much concentrate as when the roughage is hay or hay and silage. If pasture is of poor quality, the protein percentage of the concentrate should be adjusted. The percent protein in the concentrate mixture should be determined by the quality of the pasture as shown in Table 39.

## Vitamins

Current Vitamin E recommendations are to feed lactating dairy cows 400-500 IU per head per day. Vitamin E helps prevent mastitis.

## Dry Cows

Dry cows may be fed medium quality forage as the main part of their diet. This forage should be grass with no legumes. Grazing on legume pasture often raises calcium and phosphorus levels high enough to cause milk fever. With concentrate feeding, the amount of grain should be increased 1 / 2 to 1 pound per day during the last two to three weeks before calving. This will help cows get accustomed to high grain consumption, which will be required after calving. This increase also helps to reduce the possibility of the occurrence of ketosis, a metabolic disorder.

Ideally, cows should be in moderate to good condition before drying off because their bodies use feed nutrients more efficiently when lactating than when dry. Thin dry cows may be fed up to 4 to 6 pounds of home-grown grain per day. The amount should be determined by the condition of the cow. Cows in good condition should be fed little or no grain unless the roughage is of poor quality.

Soybean meal or other protein concentrate may be needed to balance the protein when dry cows are fed only corn silage.

Vitamin E is recommended for dry cows at 1,000 IU per head per day. It is included in the diet to help prevent mastitis and retained placenta.

After calving, cows should be brought to peak milk production as soon as possible. This can be done by feeding slightly more grain than is required. This gradual increase in grain should continue until there is no increase in milk production. Then the amount of grain fed should be adjusted to the milk production level.

## Young Dairy Animals

### *Birth to four months of age*

***Colostrum*** - Usually the calf is left with the cow (its mother) the first day in order to receive colostrum. Colostrum is the first milk produced by the cow after freshening. It is rich in protein, vitamins, and minerals. It also contains antibodies that help protect the calf from disease.

***Milk*** - The milk-feeding schedule is as shown in the table to the right.

| Age (Days) | Amount of Milk to Feed Daily |
|---|---|
| 0-3 | 4-6 lb* |
| 4-24 | 6-8 lb |
| 25-31 | 4-6 lb |

*colostrum or nurse cow

Recommendations for feeding are:

- Feed whole milk or an equivalent amount of milk replacer.
- Feed in two equal feedings.
- Feed the lower amount for small breeds and the higher amount for large breeds.

### *Four to twelve months of age*

The calf does not have enough rumen capacity at this age to meet energy needs from roughage alone. Feed 1 to 3 pounds of grain depending on the age, size, and condition of the animal.

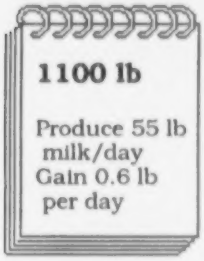
### *Twelve months to calving*

- Feed grain only if the roughage is of poor quality.
- Feed free-choice mineral mixture.
- Two months before freshening, start feeding 4 to 6 pounds of grain daily. Gradually increase to get heifers accustomed to high grain consumption at calving.

## NUTRIENT REQUIREMENT TABLE FOR DAIRY CATTLE

The table we are using to determine the energy and nutrient requirements of an example diet for lactating dairy cows is **Appendix Table 2 NR, *Recommended Nutrient Content of Diets for Dairy Cattle.*** Included in this table are also nutrients for early lactation, dry pregnant cows, calf milk replacer, and growing heifers.

# EXAMPLE DIET FOR DAIRY CATTLE




## For Lactating Dairy Cows

In this example a balanced diet will be formulated for an 1100-pound dairy cow. The cow will produce 55 pounds of 4.5% butterfat milk and is expected to gain 0.6 pound per day.

*STEP 1* **Identify the feedstuffs available for feeding this dairy cow.**
For this exercise, the following feedstuffs will be used:

alfalfa hay, corn silage, corn and cob meal, soybean meal

*STEP 2* **Determine the nutrient composition of each of the selected feedstuffs.**
Refer to Worksheet A, ***Feeds Available and Their Composition*** (page 172) for the values we will use. (Appendix Table 1C, *Composition of Selected Feeds and Their Energy Values,* was the source of this information.)

*STEP 3* **Identify the relevant life cycle information for the dairy cow being fed.**
Critical information in this example would include weight, pounds of milk produced, percent of milk butterfat, weight gain, and stage of lactation. The nutrient requirement tables are organized according to this information. Once the information is identified, the correct table to use can be identified. The necessary information for the example dairy cow has been recorded at the top of **Worksheet B, Sample 2** (page 194).

*STEP 4* **Identify the nutrient and energy requirements for the 1100-pound dairy cow.**
The necessary information, from Appendix Table 2 NR, *Recommended Nutrient Content of Diets for Dairy Cattle,* is shown at the top of the next page.

**A.** Determine the column in Appendix Table 2 NR that best represents the production stage of the example lactating cow. As this 1100-pound cow is producing 55 pounds of milk per day, the third column under "Lactating Cow Diets" is the one to use.

**B.** Record this energy and nutrient requirement information on Worksheet B, Sample 2. →

| | | |
|---|---|---|
| NEL | = | 0.73 Mcal/lb |
| CP | = | 16% |
| Ca | = | 0.60% |
| P | = | 0.38% |

| Cow Wt. (lb) | Fat (%) | Wt. Gain (lb/d) | Lactating Cow Diets — Milk Yield (lb/d) | | | | | Early Lactation (wks 0-3) | Dry Pregnant Cows | Calf Milk Replacer | Calf Starter Mix |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 900 | 5.0 | 0.50 | 14 | 29 | 43 | 58 | 74 | | | | |
| 1,100 | 4.5 | 0.60 | 18 | 36 | 55 | 73 | 91 | | | | |
| 1,300 | 4.0 | 0.72 | 23 | 47 | 70 | 93 | 117 | | | | |
| 1,500 | 3.5 | 0.82 | 26 | 52 | 78 | 104 | 130 | | | | |
| 1,700 | 3.5 | 0.94 | 29 | 57 | 86 | 114 | 143 | | | | |
| Energy | | | | | | | | | | | |
| NEL, Mcal/lb | | | 0.65 | 0.69 | 0.73 | 0.78 | 0.78 | 0.76 | 0.57 | -- | -- |
| NEM, Mcal/lb | | | -- | -- | -- | -- | -- | -- | -- | 1.09 | 0.86 |
| NEG, Mcal/lb | | | -- | -- | -- | -- | -- | -- | -- | 0.70 | 0.54 |
| ME, Mcal/lb | | | 1.07 | 1.16 | 1.25 | 1.31 | 1.31 | 1.27 | 0.93 | 1.71 | 1.41 |
| DE, Mcal/lb | | | 1.26 | 1.35 | 1.44 | 1.50 | 1.50 | 1.46 | 1.12 | 1.90 | 1.60 |
| TDN, % of DM | | | 63 | 67 | 71 | 75 | 75 | 73 | 56 | 95 | 80 |
| Protein equivalent | | | | | | | | | | | |
| Crude protein, % | | | 12 | 15 | 16 | 17 | 18 | 19 | 12 | 22 | 18 |
| UIP, % | | | 4.5 | 5.4 | 5.7 | 6.0 | 6.3 | 7.2 | -- | -- | -- |
| DIP, % | | | 7.9 | 8.8 | 9.7 | 10.4 | 10.4 | 9.7 | -- | -- | -- |
| Fiber content (min.)[b] | | | | | | | | | | | |
| Crude fiber, % | | | 17 | 17 | 17 | 15 | 15 | 17 | 22 | -- | -- |
| Acid detergent fiber, % | | | 21 | 21 | 21 | 19 | 19 | 21 | 27 | -- | -- |
| Neutral detergent fiber, % | | | 28 | 28 | 28 | 25 | 25 | 28 | 35 | -- | -- |
| Ether extract (min.), % | | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 10 | 3 |
| Minerals | | | | | | | | | | | |
| Calcium, % | | | 0.43 | 0.53 | 0.60 | 0.65 | 0.66 | 0.77 | 0.39 | 0.70 | 0.60 |
| Phosphorus, % | | | 0.28 | 0.34 | 0.38 | 0.42 | 0.41 | 0.49 | 0.24 | 0.60 | 0.40 |
| Magnesium, %[c] | | | 0.20 | 0.20 | 0.20 | 0.25 | 0.25 | 0.25 | 0.16 | 0.07 | 0.10 |
| Potassium, %[c] | | | 0.90 | 0.90 | 0.90 | 1.00 | 1.00 | 1.00 | 0.65 | 0.65 | 0.65 |
| Sodium, % | | | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.10 | 0.10 | 0.10 |
| Chlorine, % | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.20 | 0.20 | 0.20 |
| Sulfur, % | | | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.25 | 0.16 | 0.29 | 0.20 |
| Iron, ppm | | | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 100 | 50 |
| Cobalt, ppm | | | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Copper, ppm[d] | | | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Manganese, ppm | | | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Zinc, ppm | | | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Iodine, ppm[e] | | | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.25 | 0.25 | 0.25 |
| Selenium, ppm | | | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Vitamins[b] | | | | | | | | | | | |
| A, IU/lb | | | 1,450 | 1,450 | 1,450 | 1,450 | 1,450 | 1,800 | 1,800 | 1,700 | 1,000 |
| D, IU/lb | | | 450 | 450 | 450 | 450 | 450 | 450 | 540 | 270 | 140 |
| E, IU/lb | | | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 18 | 11 |

**Take note of the following guidelines** to be considered in formulating this diet: ***STEP 5***

- Half the forage dry matter will be fed as alfalfa hay and half as corn silage.
- Balance for energy first, since it is usually the most limiting factor in the diet of high-producing cows.
- Mineral deficiencies will be corrected by dicalcium phosphate, trace mineralized salt, and fat-soluble vitamins.
- Half the concentrate mix will be fed as corn and cob meal and half as soybean meal.
- Lactating cows should be fed 3.5% of their body weight in dry matter.
- Roughage will be limited to 1.75% of their body weight in dry matter.
- The calcium to phosphorus ratio should be about 1.5:1–2:1.

## Worksheet B, Sample 2 Diet Evaluation

Date 3/28/92 Prepared by *Sue Miller* Species *Dairy cow* Weight 1100 lb

Type of animal or use *Milk production 55 lb of 4.5% BF* Special considerations *Gain 0.6 lb/day*

| | As fed lb % | DM % | Energy Mcal/lb* NEM | NEG | NEL | ME | For dairy cows change lb to % CP lb % | Ca lb % | P lb % | Lysine for Swine lb | Vitamins A IU/lb | E IU/lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Daily nutrient requirements | | | | | 0.73 | | 16.0 | 0.60 | 0.38 | | | |
| **Feedstuffs in diet** | | | | | | | | | | | | |
| *Alfalfa hay (sun-cured, early bloom)* | 22 | 35.4 | | | 0.216 | | 6.4 | 0.50 | 0.08 | | | |
| *Corn silage (well-eared)* | 60 | 35.4 | | | 0.258 | | 2.9 | 0.08 | 0.08 | | | |
| ***Total of forages*** (%) | 82 | 70.8 | | | 0.474 | | 9.3 | 0.58 | 0.16 | | | |
| ***Amount of deficiency or excess from forages*** | | | | | **– 0.256** | | **– 6.7** | **– 0.02** | **– 0.22** | | | |
| *Corn and cob meal* | 12 | 19.4 | | | 0.169 | | 1.75 | 0.14 | 0.05 | | | |
| *Soybean meal* | 6 | 9.9 | | | 0.087 | | 4.94 | 0.03 | 0.07 | | | |
| ***Total of concentrates*** (%) | 18 | 29.3 | | | 0.256 | | 6.69 | 0.17 | 0.12 | | | |
| ***Amount of deficiency or excess*** | **0** | **0** | | | **0** | | **– 0.01** | **+ 0.15** | **– 0.10** | | | |
| *Dicalcium phosphate & Trace mineralized salt* | | | | | | | | | | | | |
| Total in diet | 100 | 100 | | | 0.73 | | 15.99 | 0.75 | 0.28 | | | |
| Oversupply | | | | | 0 | | | + 0.15 | | | | |
| Undersupply | | | | | | | – 0.01 | | – 0.10 | | | |

* Use the appropriate energy designation for the livestock to be fed.

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**Formulate the diet.** The following steps will be used in balancing the diet for the lactating cow. ***STEP 6***

A. Determine the energy content of the forage mixture and the concentrate mixture.
B. Determine the percentages of forage and concentrate to use (using square method).
C. Determine the nutrients provided by the forages and total them.
D. Determine whether any nutrient deficiencies exist.
E. Determine the amount of corn and cob meal and SBM needed for the concentrate (using simultaneous equations).
F. Determine energy and nutrients supplied by the concentrates.
G. Total all the nutrients provided in the diet and check for an undersupply.
H. Convert the dry matter to an as-fed diet.

---

**A.** Determine the energy content of the forage mixture and the concentrate mixture (referring to Worksheet A, page 172, for the components).

1. Determine the average energy value of the forage mixture.

| | | |
|---|---|---|
| alfalfa hay | 0.61 | NEL Mcal/lb DM |
| corn silage | + 0.73 | NEL Mcal/lb DM |
| *average* | 1.34 ÷ 2 = | 0.67 Mcal/lb in forage |

2. Determine the average energy value of the concentrate component. (We will assume at this point that the concentrate will temporarily consist of 50% corn and cob meal and 50% SBM. This simply gives a starting point after which further changes are possible.)

| | | |
|---|---|---|
| corn and cob meal | 0.87 | NEL Mcal/lb DM |
| soybean meal | + 0.88 | NEL Mcal/lb DM |
| *average* | 1.75 ÷ 2 = | 0.875 NEL Mcal/lb DM forage |

**B.** Determine the percentages of forage and concentrate to use in the diet by using the square method.

| Feed | NEL Mcal | | Parts | Total Parts | Percent | Amount of Each Feed to Use in Mix |
|---|---|---|---|---|---|---|
| forage | 0.67 | 0.73 NEL Mcal/lb DM in diet | 0.145 | ÷ 0.205 = | 0.707 x 100 = | 70.7% |
| concentrate | 0.875 | | + 0.06 | ÷ 0.205 = | 0.293 x 100 = | 29.3% |
| | | Total | 0.205 | | | 100 % |

**C.** Determine the nutrient amounts that are provided by the forages; add amounts to get total nutrients. Record on Worksheet B, Sample 2.

| | NEL Mcal | CP % | Ca % | P % |
|---|---|---|---|---|
| alfalfa nutrient content | 0.61 Mcal | 18.0% | 1.41% | 0.22% |
| | 0.61 | 0.18 | 0.014 | 0.0022 |
| % alfalfa in diet | X .354 | X .354 | X .354 | X .354 |
| amount of nutrient provided by alfalfa | 0.216 Mcal | 0.064 (6.4%) | 0.005 (.5%) | 0.0008 (.08%) |

| | NEL Mcal | CP % | Ca % | P % |
|---|---|---|---|---|
| corn silage nutrient content | 0.73 Mcal | 8.1% | 0.23% | 0.22% |
| | 0.73 | .081 | .0023 | .0022 |
| % corn silage in diet | X .354 | X .354 | X .354 | X .354 |
| amount of nutrient provided by corn silage | 0.258 Mcal | 0.029 (2.9%) | .0008 (.08%) | 0.0008 (.08%) |

Add together:

| | NEL Mcal | CP % | Ca % | P % |
|---|---|---|---|---|
| alfalfa hay | 0.216 | 6.4 % | 0.5 % | 0.08 % |
| corn silage | + 0.258 | + 2.9 | + 0.08 | + 0.08 |
| Total nutrients | 0.474 Mcal | 9.3 % | 0.58 % | 0.16 % |

**D.** Determine whether any nutrient deficiencies exist.

| | NEL Mcal/lb | CP % | Ca % | P % |
|---|---|---|---|---|
| Nutrients provided | 0.474 | 9.3 % | 0.58 % | 0.16 % |
| Nutrients required | − 0.730 | − 16.0 | − 0.60 | − 0.38 |
| Undersupply | − 0.256 Mcal | − 6.7 % | − 0.02 % | − 0.22 % |

**E.** Determine the amount of corn and cob meal and SBM needed for the concentrate to correct the 6.7% CP and 0.256 Mcal deficiencies. Use simultaneous equations to solve for both nutrients at the same time.

***Formula***

$$\begin{pmatrix}\text{Amount of nutrient}\\ \text{in Feed 1}\end{pmatrix}\begin{pmatrix}\text{Amount of Feed 1}\\ \text{needed}\end{pmatrix} + \begin{pmatrix}\text{Amount of nutrient}\\ \text{in Feed 2}\end{pmatrix}\begin{pmatrix}\text{Amount of Feed 2}\\ \text{needed}\end{pmatrix} = \begin{matrix}\text{Total amount of}\\ \text{nutrient in diet}\end{matrix}$$

***Equation for NEL***

(0.87 corn & cob Mcal/lb) ( x ) + (0.88 soybean Mcal/lb) ( y ) = 0.256 Mcal/lb

***Equation for CP***

(0.09 corn & cob CP) ( x ) + (0.499 soybean CP) ( y ) = 0.067 Mcal/lb

☞ Solve for **x**, the percent of corn and cob meal needed.

$$\begin{array}{rcl} 0.87x + 0.88y & = & 0.256 \\ 0.09x + 0.499y & = & 0.067 \end{array}$$

$$\begin{array}{rcl} 0.87x + 0.88y & = & 0.256 \\ \times\ 0.499 & & \\ \hline 0.434x + 0.439y & = & 0.128 \end{array}$$

$$\begin{array}{rcl} 0.09x + 0.499y & = & 0.067 \\ \times\ 0.88 & & \\ \hline 0.079x + 0.439y & = & 0.059 \end{array}$$

$$\begin{array}{rcl} 0.434x + 0.439y & = & 0.128 \\ 0.079x + 0.439y & = & 0.059 \\ \hline 0.355x & = & 0.069 \end{array}$$

$x = 0.069 \div 0.355$

$x = 0.194$ or 19.4% corn and cob meal in diet

☞ Solve for **y**, the percent of soybean meal needed.

$$\begin{array}{rcl} 0.87x + 0.88y & = & 0.256 \\ (0.87 \cdot 0.194) + 0.88y & = & 0.256 \\ 0.169 - 0.169 + 0.88y & = & 0.256 - 0.169 \\ 0.88y & = & 0.087 \\ 0.88y & = & 0.087 / 0.88 \\ y & = & 0.099 \text{ or } 9.9\% \text{ soybean meal in diet} \end{array}$$

***Check calculations***

Be sure to check your answers. Errors in math can cause incorrect formulations which will affect your animals' health and production.

Remember, **x** = 19.4% corn and cob meal, and **y** = 9.9 % soybean meal.

$$\begin{array}{rcl} \text{NEL} = 0.87x + 0.88y & = & 0.256 \\ (0.87 \cdot 0.194) + (0.88 \cdot 0.099) & = & 0.256 \\ 0.169 + 0.087 & = & 0.256 \\ 0.256 & = & 0.256 \checkmark \end{array}$$

$$\begin{array}{rcl} \text{CP} = 0.09x + 0.499y & = & 0.067 \\ (0.09 \cdot 0.194) + (0.499 \cdot 0.099) & = & 0.067 \\ .0175 + .0494 & = & 0.0669 \text{ or } .067 \\ 0.067 & = & 0.067 \checkmark \end{array}$$

---

(F.) Determine the energy and nutrients supplied by the concentrates.

| % corn cob meal in diet | X | Nutrient content in corn & cob meal | = | % of nutrient provided by C & C meal in the total mix |
|---|---|---|---|---|
| .194 | X | 0.87 Mcal NEL/lb | = | 0.169 Mcal |
| .194 | X | 0.09 CP % | = | .0175 or 1.75% CP |
| .194 | X | 0.007 Ca % | = | .0014 or 0.14% Ca |
| .194 | X | 0.0027 P % | = | .0005 or 0.05% P |

| % SBM in diet | X | Nutrient content in soybean meal | = | % of nutrient provided by SBM in the total mix |
|---|---|---|---|---|
| .099 | X | 0.88 Mcal NEL/lb | = | 0.087 Mcal |
| .099 | X | 0.499 CP % | = | 0.0494 or 4.94% CP |
| .099 | X | 0.0034 Ca % | = | 0.0003 Mcal or 0.03% Ca |
| .099 | X | 0.0070 P % | = | 0.0007 Mcal or 0.07% P |

The percent of nutrients provided by corn and cob meal and soybean meal has been recorded on Worksheet B, Sample 2.

(G.) Using Worksheet B, Sample 2, determine what nutrient deficiencies still remain.

- Record the energy and nutrient information from the two concentrates on the worksheet.
- Add the energy and nutrient values for the two concentrates to obtain the total.
- Add the forage totals and concentrate totals.
- Compare the nutrient requirement with the nutrients provided and identify any remaining deficiencies.

The slight deficiency of crude protein results from rounding off numbers; this will not present a problem. A deficiency of phosphorus does exist and needs to be corrected.

Dicalcium phosphate can be added to supply the needed phosphorus. Trace mineralized salt and any necessary vitamins should also be mixed into the diet. Dairy diets typically reserve 1-2% of the diet for these ingredients.

(H.) Convert the example diet from 100% dry matter to as-fed percentages. With the as-fed percentages you will be able to formulate the actual diet.

| Feed | % Feed in diet as DM | % DM/ 100 | Parts | | % Feed in diet as-fed |
|---|---|---|---|---|---|
| alfalfa | 35.4 | + 0.90 = | 39.3 | + 180 = 0.22 X 100 = | 22 % |
| corn silage | 35.4 | + 0.33 = | 107.3 | + 180 = 0.60 X 100 = | 60 |
| corn & cob meal | 19.4 | + 0.87 = | 22.3 | + 180 = 0.12 X 100 = | 12 |
| soybean oil meal | 9.9 | + 0.89 = | 11.1 | + 180 = 0.06 X 100 = | 6 |
| | | Total | 180 | | 100 % |

- Therefore, in one ton of mixed diet we would have:

| Feed | Parts of feed in diet as-fed | lb feed in one ton |
|---|---|---|
| alfalfa | 0.22 X 2000 lb = | 440 lb |
| corn silage | 0.60 X 2000 lb = | 1200 lb |
| corn & cob meal | 0.12 X 2000 lb = | 240 lb |
| soybean oil meal | 0.06 X 2000 lb = | 120 lb |
| dical. & trace mineralized salt | | |

# HORSES

## GUIDELINES FOR FEEDING HORSES

### Water Requirements

- 0.5 gallon per 100 pounds body weight in cool weather
- 1.5+ gallons per 100 pounds body weight if in conditions of excessive heat, work, and/or heavy lactation

It is best to wait 30-90 minutes for a hot horse to cool down before allowing it to drink all it wants. Colic or founder could result if the body has not cooled down adequately.

### Roughage

All diets for horses should contain adequate amounts of roughage. To keep their digestive systems functioning properly, horses should either have access to pasture or be fed long roughage (not chopped) in their diet.

Mature horses that are not being used for hard work or reproduction can live very well on grass or a good quality grass hay without grain.

Some rules of thumb are:

- All diets should consist of at least 50 percent roughage.
- Feed horses at least 1 percent of their body weight per day of good quality roughage.

*or*

- Allow horses enough feeding time in pasture to consume at least 1 percent of their body weight in dry matter per day.

Grazing horses and horses given free access to hay will consume 2 to 2.5% of their body weight as dry matter in a 24-hour period.

Horses needing more energy than can be supplied by roughages alone should be provided a diet containing at least 1 pound of roughage per 100 pounds of live body weight. The remainder of the energy requirement can be supplied by concentrates.

### Amino Acids

The diet for horses, as for swine, must be in balance for the amino acid lysine. A deficiency of lysine will cause poor growth and development in young horses. In mature horses, lysine deficiency can cause reduced feed intake, body tissue loss, poor hair coat, and reduced hoof growth. The common feed ingredients used for horses usually supply adequate levels of lysine. It is becoming increasingly popular to balance horse diets on lysine rather than crude protein.

## Feeding Recommendations for Specific Classes of Horses

### *Geldings and Open Mares*

***Mature idle horses*** - Pasture free-choice or feed 2 pounds of hay for each 100 pounds of body weight; i.e. 2% of body weight in hay.

***Light work*** (under 3 hours per day) - Feed 1/4 to 1/2 pound of grain and 1 1/4 to 1 1/2 pounds of hay for each 100 pounds of body weight.

***Medium work*** (3 to 5 hours per day) - Feed 1 pound of grain and 1 pound of hay for each 100 pounds of body weight.

***Heavy work*** (over 5 hours per day) - Feed 1 1/4 to 1 1/2 pounds of grain and 1 pound of hay for each 100 pounds of body weight.

Mineral mixtures may be mixed with the grain or fed free-choice. Loose trace mineralized salt should be fed free-choice.

Reduce grain allowance of horses on non-work days by about 50% to prevent azoturia, a condition causing muscle dysfunction and damage.

### *Pregnant Mares*

Most mares are able to met their nutritional needs during lactation on good quality pasture. Grain may be needed in the diet when pasture quality is low.

Brood mares in late pregnancy should be fed good quality roughages or a combination of roughages and concentrates. This diet should allow the mare to store body fat that can be used for energy needs during early lactation and rebreeding.

During the last three months of gestation, follow these recommendations for the mare's diet:

- Provide crude protein at 11-12% of the diet.
- Increase energy level by 5-10%.
- Double the Vitamin A allowance.
- Provide the correct calcium/phosphorus mineral mixture with trace mineralized salt.

### *Lactating Mares*

During the 4- to 6-month lactation period, the following guidelines can be helpful.

- Feed 1 pound of quality hay per 100 pounds of body weight.
- Add corn and oats as needed to supply required energy.
- Consider adding soybean oil meal to increase protein. But palatability and separation of ingredients may be a problem. Molasses can be added as a binder.
- Keep the protein level at 14%.
- Maintain the free choice of minerals, vitamins, and salt as given during gestation.

### *Foals*

Mare's milk production will peak in the two months after foaling. During this time, milk should supply the foal's needs unless the mare is a poor producer. Four months after foaling, the mare will be able to provide only about 50% of the energy and protein needed by the foal.

- The foal should be gradually introduced to the feeds it will be eating. This can begin as early as one week of age.
- Foals learn to eat grain more quickly if they eat with their mothers first.
- The creep feed should be at least 16% protein.
- The foal will probably eat about a pound of feed a day during its first month. It can gradually increase to as much as 10 pounds per day at weaning.
- Foals less than six months of age eat 2 to 4% of their liveweight in dry feed per day.
- At 4 to 6 months of age, the foal should be weaned. It should receive 3/4 to 1 pound of concentrate mixture daily per 100 pounds live weight plus access to quality hay. Be sure the minerals are balanced.

## NUTRIENT REQUIREMENT TABLE FOR HORSES

In formulating a sample diet for horses, digestible energy (DE) and crude protein (CP) values will be used as recommended by the National Research Council. Nutrient requirement tables for different weights of horses are available. The one we will use is **Appendix Table 3 NR, *Daily Nutrient Requirements of Horses*** *(880-lb mature weight)*. Data in this table are closest to what we need for an example 900-pound mare. The following life cycle stages are included:

***Mature horses***

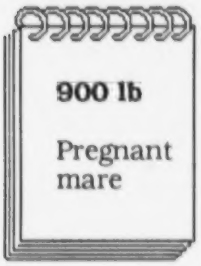
Maintenance
Stallions (breeding season)
Pregnant mares
  9 months, 10 months, 11 months
Lactating mares
  Foaling to 3 months
  3 months to weaning
Working horses
  Light work *(examples:* horses used in Western and English pleasure, bridle path hack, equitation, etc.)
  Moderate work *(examples:* horses used in ranch work, roping, cutting, barrel racing, jumping, etc.)
  Intense work *(examples:* horses used in race training, polo, etc.)

***Growing horses***

Weanling, 4 months
Weanling, 6 months
  Moderate growth
  Rapid growth
Yearling, 12 months
  Moderate growth
  Rapid growth
Long yearling, 18 months
  Not in training
  In training
Two-year-old, 24 months
  Not in training
  In training

Before you can use the table properly, you will need to determine or estimate the weight of the horse for which the diet is being formulated. Use the nearest weight you can find. The row to use in this table depends upon the life cycle stage and the use being made of the horse.

# EXAMPLE DIET FOR HORSES




## For Pregnant Mares

In this example we will be formulating a balanced diet for a 900-pound pregnant mare.

***STEP 1*** **Identify the feedstuffs available for feeding the 900-pound mare.** For this exercise, the principal feedstuffs will be:

red clover-timothy hay (sun-cured, full bloom)
oats

Note that these feedstuffs are recorded on **Worksheet B, Sample 3** (page 203).

***STEP 2*** **Determine the nutrient composition of the selected feedstuffs.** The information used in this example came from the *United States-Canadian Tables of Feed Compositions* manual. The values were recorded directly on Worksheet B, Sample 3. Note that this worksheet has been modified to include a column for ***digestible energy*** (DE).

***STEP 3*** **Identify the life cycle information for the horse being fed.** Critical information in this example would include the horse's weight, sex, stage of gestation, and use. This information is recorded at the top of Worksheet B, Sample 3.

***STEP 4*** **Identify the nutrient and energy requirements for this 900-pound pregnant mare.** The information needed, shown below from Appendix Table 3 NR, is recorded on Worksheet B, Sample 3 in the top row.

| Animal | Weight (lb) | Daily Gain (lb) | DE (Mcal) | Crude Protein (lb) | Lysine (lb) | Calcium (lb) | Phosphorus (lb) | Vitamin A (1000 IU) |
|---|---|---|---|---|---|---|---|---|
| ***Mature horses*** | | | | | | | | |
| Maintenance | 882 | | 13.4 | 1.18 | 0.042 | 0.035 | 0.024 | 12 |
| Stallions (breeding season) | 882 | | 16.8 | 1.47 | 0.051 | 0.044 | 0.033 | 18 |
| Pregnant mares | | | | | | | | |
| 9 months | 882 | | 14.9 | 1.44 | 0.051 | 0.062 | 0.046 | 24 |
| 10 months | | | 15.1 | 1.47 | 0.051 | 0.064 | 0.048 | 24 |
| 11 months | | | 16.1 | 1.56 | 0.055 | 0.068 | 0.051 | 24 |
| Lactating mares | | | | | | | | |
| Foaling to 3 months | 882 | | 22.9 | 2.51 | 0.088 | 0.099 | 0.064 | 24 |
| 3 months to weaning | 882 | | 19.7 | 1.85 | 0.064 | 0.064 | 0.040 | 24 |
| Working horses | | | | | | | | |
| Light work[a] | 882 | | 16.8 | 1.47 | 0.051 | 0.044 | 0.033 | 18 |

## Worksheet B, Sample 3 Diet Evaluation

**Date** 6/15/92 **Prepared by** *Jane Doe* **Species** *Horse* **Weight** 900 lb

**Type of animal or use** *Brood mare* **Special considerations** *11th month of gestation*

| | As fed lb | DM lb | Energy Mcal* | | | | For swine change lb to % | | | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DE | NEG | NEL | ME | CP lb | Ca lb | P lb | Lysine lb | Vitamins IU A | D |
| Daily nutrient requirements | | | 16.1 | | | | 1.56 | 0.068 | 0.051 | 0.055 | 24,000 | |
| Feedstuffs in diet | | | | | | | | | | | | |
| *Red clover-timothy hay* | 16.2 | 14.4 | 12.38 | | | | 1.73 | 0.141 | 0.033 | | | |
| *Oats, grain* | 2.9 | 2.6 | 3.77 | | | | 0.35 | 0.002 | 0.010 | | | |
| | | | | | | | | | | | | |
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| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| Total in diet | 19.1 | 17.0 | 16.15 | | | | 2.08 | 0.143 | 0.043 | | | |
| Oversupply | -- | -- | 0.05 | | | | 0.52 | 0.075 | | | | |
| Undersupply | -- | -- | | | | | | | 0.008 | | | |

* Use the appropriate energy designation for the livestock to be fed.

*STEP 5* **The following feeding guidelines should be kept in mind** as we proceed to formulate the diet:

- Digestible energy is used instead of net energy or metabolizable energy when formulating diets for horses.
- Horses given free access to hay will consume 2 - 2.5% of their body weight in hay dry matter per day.
- This example horse will be provided 2% of her body weight in forage.
- Hay to be fed is approximately 50% red clover and 50% timothy.

*STEP 6* **Formulate the diet.**
We will be using the trial and error method to balance this diet due to the small number of feeds to be used. Remember that the mare can be fed 2% of her body weight in dry matter. Of this 2%, we will start off assuming that 80% can consist of forage and 20% can consist of grain.

**A.** Calculate pounds of dry matter for the diet.

mare weight X % body weight = lb DM
900 lb X 0.02 = 18 lb DM

**B.** Determine how much of each feed will be used to meet the DM requirement.

18 lb DM X .80 = 14.4 lb hay
18 lb DM X .20 = 3.6 lb grain

**C.** Calculate the nutrient content of the mixed legume and grass hay. We will assume a 50:50 mix of red clover and timothy in the hay. Ideally, the hay would have been analyzed for its nutrient content. As this information is not available, we will use the information presented in the Feed Composition tables. (See Appendix Table 1C.)

**Nutrient content per lb of mixed red clover–timothy hay**

| | Mcal/lb | CP% | Ca% | P % |
|---|---|---|---|---|
| red clover | 0.90 | 16.0 | 1.53 | 0.25 |
| timothy | + 0.81 | + 8.1 | + 0.43 | + 0.20 |
| Total in 2 lb | 1.71 Mcal | 24.1% | 1.96% | 0.45% |
| **Average for 1 lb mixed hay** | **0.86 Mcal** | **12.05%** | **0.98%** | **0.23%** |

**Nutrient content of 14.4 lb of mixed hay**

| | | | |
|---|---|---|---|
| 0.86 Mcal | 0.12 CP | 0.0098 Ca | 0.0023 P |
| X 14.4 lb | X 14.4 lb | X 14.4 lb | X 14.4 lb |
| 12.38 Mcal | 1.73 lb | 0.141 lb | 0.033 lb |

**D.** Calculate nutrient content in the 3.6 pounds of oats.

| *In 1 lb of oats:* | 1.45 Mcal DE | 13.3% CP | 0.07% Ca | 0.38% P |
|---|---|---|---|---|
| | 1.45 Mcal | 0.133 CP | 0.0007 Ca | 0.0038 P |
| X | 3.6 lb | X 3.6 lb | X 3.6 lb | X 3.6 lb |
| | 5.22 Mcal | 0.48 lb | 0.003 lb | 0.014 lb |

**E.** Total the feed ingredients and determine whether an oversupply or undersupply of nutrients exists.

| | Mcal/lb | CP lb | Ca lb | P lb |
|---|---|---|---|---|
| mixed hay | 12.38 | 1.73 | 0.141 | 0.033 |
| oats | + 5.22 | + 0.48 | + 0.003 | + 0.014 |
| Totals | 17.60 | 2.21 | 0.144 | 0.047 |
| | 17.60 | 2.21 | 0.144 | 0.047 |
| requirements | −16.10 | −1.56 | − 0.068 | − 0.051 |
| **Undersupply/ Oversupply** | **+ 1.50** | **+ 0.65** | **+ 0.076** | **− 0.004** |

The supply of nutrients required has been exceeded in all cases except phosphorus. Let's take care of the excesses first. If we reduce the quantity of oats fed, the excess energy provided is also quickly reduced.

1 ) Calculate the nutrients contained in I lb of oats.

| | Mcal/lb | CP lb | Ca lb | P lb |
|---|---|---|---|---|
| Nutrient content of oats | 1.45 Mcal | 13% | 0.07% | 0.38% |
| | 1.45 | 0.13 | .0007 | .0038 |
| | X 1.0 | X 1.0 | X 1.0 | X 1.0 |
| Nutrient content in 1 lb of oats | 1.45 | 0.13 | .0007 (or .001) | .0038 (or .004) |

2 ) Note that if we subtract 1 lb of oats from the total diet, we are close to having all nutrients in balance.

| | Mcal/lb | CP lb | Ca lb | P lb |
|---|---|---|---|---|
| Total | 17.60 | 2.21 | 0.144 | 0.047 |
| minus 1 lb oats | − 1.45 | − 0.13 | − 0.001 | − 0.004 |
| Total | 16.15 | 2.08 | 0.143 | 0.043 |
| | 16.15 | 2.08 | 0.143 | 0.043 |
| requirements | −16.10 | −1.56 | − 0.068 | − 0.051 |
| **Undersupply/ Oversupply** | **+ 0.05** | **+ 0.52** | **+ 0.075** | **− 0.008** |

The diet is now acceptable. Energy and protein levels are reasonable. We are feeding more calcium than is required, but this is not a problem. Phosphorus is slightly deficient. If a small amount of monocalcium phosphate is added to a loose trace mineralized salt mix, this problem is remedied.

**F.** Calculate the as-fed weights of each feed.

| | lb | | % DM | | % as-fed |
|---|---|---|---|---|---|
| Red clover-timothy hay | 14.4 | ÷ | .89 | = | 16.2 lb |
| Oats | 2.6 | ÷ | .89 | | 2.9 lb |
| | | | Total | | 19.1 lb |

# SHEEP

## GUIDELINES FOR FEEDING SHEEP

A large part of the feed for most classes of sheep comes from grazing. With dry-lot feeding, 50 to 100% of the feed can be supplied with roughages.

### Ewes

***Fifteen Weeks into Gestation Period***

Feed 3 to 3.5% of the ewe's body weight in hay per day. A 140-pound ewe should receive 4 to 5 pounds of hay per day. To supply her daily energy needs, any of these amounts of roughages can be fed. →

| Roughage | Amount |
|---|---|
| Legume hay | 3.5 lb |
| Grass hay | 4.0 lb |
| Haylage | 6.0 lb |
| Corn silage* | 7.5 lb |

* Feed one-third pound of protein concentrate per day when corn silage is fed.

***During Breeding Period***

If ewes are on a legume pasture, they should be removed two weeks before breeding starts and placed on grass pasture. They should be fed 1/2 pound of grain (corn-oats) two weeks before and one week after the breeding season starts.

***During Gestation Period***

For the first 3 1/2 months of pregnancy, average to good quality pasture or hay fed free-choice is adequate. The hay should be a legume or legume-grass mixture.

The last 1 1/2 months of pregnancy for winter or spring lambing, feed:

- 4-5 pounds of hay plus 1/2 to 3/4 pound of shelled corn, or
- 2-3 pounds of hay plus 1 1/2-2 pounds of shelled corn, or
- 7-8 pounds of corn silage plus 1 pound of shelled corn and 1/4 to 1/2 pound of protein concentrate.

***During Lactation Period***

Feed the ewe lightly for a day or two after lambing. Provide plenty of fresh water. By the third day, feed:

- 3 - 3 1/2 pounds of hay plus 3-3 1/2 pounds of shelled corn, or
- 9-11 pounds of corn silage plus 1 1/2-2 pounds of shelled corn plus 1/2 pound of protein concentrate.

## Lambs

Start creep feeding when lambs are approximately ten days old. Diet: 6 parts cracked corn, 2 parts oats or bran, 2 parts protein concentrate. When lambs are four weeks old, feed a concentrate mixture containing 18% crude protein. Continue this until the lambs are weaned.

Late lambs can be produced for market from grazing on good pasture. For finishing lambs on dry lot, feed 2 pounds of shelled corn, 2 pounds of legume hay, and 1/2 pound of protein concentrate daily. Lambs on full feed should gain approximately 1/2 pound per day.

# NUTRIENT REQUIREMENT TABLE FOR SHEEP

The table we will use to determine the energy and nutrient requirements of sheep is **Appendix Table 4 NR, *Daily Nutrient Requirements of Sheep***. In this table, sheep are separated according to their different life cycle stages: breeding ewes, replacement ewe and ram lambs, and growing and finishing lambs. The categories of these stages are as follows:

***For ewes:***

Maintenance
Flushing - 2 weeks prebreeding and first 3 weeks of breeding
Nonlactating - first 15 weeks of gestation
Last 4 weeks gestation (130-150% lambing rate expected) or last 4 to 6 weeks lactation nursing singles
Last 4 weeks gestation (180-225% lambing rate expected)
First 6 to 8 weeks lactation nursing singles or last 4 to 6 weeks lactation nursing twins
First 6 to 8 weeks lactation nursing twins

***For ewe lambs:***

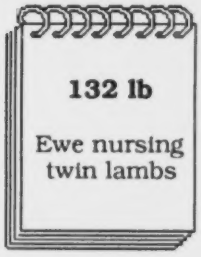
Nonlactating - first 15 weeks gestation
Last 4 weeks gestation (100-120% lambing rate expected)
Last 4 weeks gestation (130-175% lambing rate expected)
First 6 to 8 weeks lactation nursing singles (wean by 8 weeks)
First 6 to 8 weeks lactation nursing twins (wean by 8 weeks)

**Replacement ewe lambs**
**Replacement ram lambs**
**Lambs finishing** - 4 to 7 months old
**Early weaned lambs - moderate growth potential**
**Early weaned lambs - rapid growth potential**

The weight category of ewes is based on normal weight. If a ewe normally weighs 130 pounds during early gestation, this should also be the weight category for late gestation even though she is likely to weigh more.

# EXAMPLE DIET FOR SHEEP

## For Breeding Ewes




The following example will show how Appendix Table 4 NR and Worksheet B can be used to determine a ewe's daily energy and nutrient requirements. A balanced diet will be formulated for a 132-pound ewe nursing twin lambs during the first 8 weeks of lactation.

For sheep the metabolizable energy (ME) value is used to express energy requirements and energy values of feedstuffs.

***STEP 1*** **Identify the feedstuffs that are available for feeding to the example ewe.** For this exercise the following feedstuffs will be used:

alfalfa hay (sun-cured, early bloom)
barley (grain)

***STEP 2*** **Determine the nutrient composition and energy values of the selected feedstuffs.** Refer to Worksheet A (page 172) for the values we will use. (Appendix Table 1C, *Composition of Selected Feeds and Their Energy Values*, was the source of this information.)

***STEP 3*** **Identify the ewe's life cycle stage information.** Turn to **Worksheet B, Sample 4** (page 209). At the top is the necessary information for the example ewe for which the diet is being formulated.

***STEP 4*** **Identify the dry matter intake and the energy and nutrient requirements.** This information, shown here from Appendix Table 4 NR, is recorded on Worksheet B, Sample 4.

| Body Weight (lb) | Weight Change/ Day (lb) | Dry Matter[a] (lb) | Dry Matter[a] (% body weight) | Crude Protein (lb) | Energy ME (Mcal) | Ca (lb) | P (lb) | Vitamin A (IU) | Vitamin E (IU) |
|---|---|---|---|---|---|---|---|---|---|
| **EWES[b]** | | | | | | | | | |
| ***First 6-8 weeks lactation nursing twins*** | | | | | | | | | |
| 110 | - 0.13 | 5.3 | 4.8 | 0.86 | 5.6 | 0.0231 | 0.0161 | 5,000 | 36 |
| → 132 | - 0.13 | 5.7 | 4.3 | 0.89 | 6.1 | 0.0236 | 0.0170 | 6,000 | 39 |
| 154 | - 0.13 | 6.2 | 4.0 | 0.92 | 6.6 | 0.0242 | 0.0179 | 7,000 | 42 |
| 176 | - 0.13 | 6.6 | 3.8 | 0.96 | 7.0 | 0.0247 | 0.0190 | 8,000 | 45 |
| 198 | - 0.13 | 7.0 | 3.6 | 0.99 | 7.5 | 0.0251 | 0.0198 | 9,000 | 48 |

The energy and nutrient requirements for sheep during other life-cycle stages can be determined by locating the subsection in the table that best describes the appropriate life cycle stage.

***STEP 5*** **Some of the guidelines for feeding lactating ewes are:**

- Feed lightly for a day or two after lambing.
- Provide plenty of fresh water.
- By the third day, provide the ewe with full feed.

## Worksheet B, Sample 4 Diet Evaluation

**Date** 4/2/92 **Prepared by** *Jane Doe* **Species** *Sheep* **Weight** 132 lb

**Type of animal or use** *Ewe nursing twins* **Special considerations** *Twin lambs - first 8 weeks lactation*

| | As fed lb | DM lb | Energy Mcal* | | | | For swine change lb to % | | | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NEM | NEG | NEL | ME | CP lb | Ca lb | P lb | Lysine for Swine lb | Vitamin IU A | Vitamin IU D |
| Daily nutrient requirements | | 5.7 | | | | 6.1 | 0.89 | 0.024 | 0.017 | | 6,000 | 39 |
| Feedstuffs in diet | | | | | | | | | | | | |
| *Alfalfa hay (sun cured, early bloom)* | 5.56 | 5.0 | | | | 5.05 | 0.90 | 0.0700 | 0.0110 | | | |
| *Barley grain* | 0.80 | 0.7 | | | | 1.06 | 0.096 | 0.0004 | 0.0027 | | | |
| | | | | | | | | | | | | |
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| | | | | | | | | | | | | |
| Total in diet | 6.36 | 5.7 | | | | 6.11 | 0.996 | 0.070 | 0.0137 | | | |
| Oversupply | | - - | | | | 0.01 | 0.106 | 0.046 | | | | |
| Undersupply | | - - | | | | | | | 0.0033 | | | |

* Use the appropriate energy designation for the livestock to be fed.

***STEP 6*** **Formulate the diet.** The steps to be used in balancing this diet are as follows:

**A.** Balance the diet for energy using the square method.
**B.** Convert percentages to pounds in the 5.7-pound diet.
**C.** Calculate the nutrients provided by each feed.
**D.** Identify any deficiencies.
**E.** Convert pounds of dry matter to pounds of feed as-fed.

**A.** Using the square method, balance for a diet that contains the required energy level: 1.07 Mcal of metabolizable energy (ME).

| Feeds | Mcal Energy | | Parts | Total Parts | Percent of Each Feed to Use in Mix |
|---|---|---|---|---|---|
| alfalfa hay | 1.01 | | 0.42 | ÷ 0.48 | = 0.875 X 100 = 87.5% |
| | | 1.07 Mcal | | | |
| barley grain | 1.49 | | + 0.06 | ÷ 0.48 | = 0.125 X 100 = 12.5% |
| | | Total | 0.48 total parts | | 100% |

**B.** Calculate the amount of each feedstuff that will be needed to make a 5.7 lb diet. This step is necessary because nutrient requirements for the sheep are given in **pounds** of DM/day, while the feed composition information is given in **percents.**

| | % of feedstuff in diet | | lb DM in diet | | |
|---|---|---|---|---|---|
| alfalfa hay | .875 | X | 5.7 | = | **4.99** lb rounded off to 5.0 |
| barley grain | .125 | X | 5.7 | = | **0.71** lb rounded off to 0.7 |
| | | | | | 5.70 lb |

**C.** Calculate the nutrients provided by this diet.

1. Calculate nutrients in alfalfa hay.
2. Calculate nutrients in barley.
3. Add up nutrients in each feed to get total nutrients.

| 1 | ME Mcal | CP % | Ca % | P % |
|---|---|---|---|---|
| alfalfa nutrient content | 1.01 Mcal | 18.0% | 1.41% | 0.22% |
| | 1.01 | 0.18 | 0.014 | 0.0022 |
| lb alfalfa hay in diet | X 5.0 | X 5.0 | X 5.0 | X 5.0 |
| | 5.05 Mcal | 0.90 lb | 0.07 lb | 0.011 lb |

2

| | ME Mcal | CP % | Ca % | P % |
|---|---|---|---|---|
| barley grain nutrient content | 1.49 | 13.5 | 0.05 | 0.38 |
| | 1.49 | 0.135 | 0.0005 | 0.0038 |
| lb barley in diet | X 0.71 | X 0.71 | X 0.71 | X 0.71 |
| | 1.06 Mcal | 0.096 lb | 0.0004 lb | 0.0027 lb |

3

| | ME Mcal | CP lb | Ca lb | P lb |
|---|---|---|---|---|
| alfalfa hay | 5.05 | 0.90 | 0.07 | 0.0110 |
| barley grain | + 1.06 | + 0.096 | + 0.0004 | + 0.0027 |
| Total nutrients | 6.11 Mcal | 0.996 lb | 0.0704 lb | 0.0137 lb |

**D.** Determine whether any nutrients are deficient.

| | ME Mcal | CP lb | Ca lb | P lb |
|---|---|---|---|---|
| Nutrients provided | 6.11 | 0.996 | 0.070 | 0.0137 |
| Nutrients required | − 6.10 | − 0.890 | − 0.024 | − 0.0170 |
| Undersupply/ Oversupply | + 0.01 | + 0.106 | + 0.046 | − 0.0033 |

Energy and crude protein and calcium requirements have been met by this diet. Phosphorus is deficient by a small amount. A free-choice mineral mixture that contains phosphorus should be provided to the ewe to help correct this deficiency.

**E.** Convert pounds of dry matter to pounds of feed on an as-fed basis.

| | lb DM in diet | | % moisture | | lb of feed as-fed |
|---|---|---|---|---|---|
| alfalfa hay | 5.0 | + | 0.90 | = | **5.56** lb of alfalfa |
| barley grain | 0.7 | + | 0.88 | = | **0.80** lb of barley grain |

# SWINE

## GUIDELINES FOR FEEDING SWINE

### Sows and Gilts

***During Gestation*** Restrict feed intake per animal to 4 to 5 pounds of 14% crude protein diet daily.

- Sows should gain between 50 and 75 pounds and gilts between 70 and 100 pounds during gestation.

***Before and After Farrowing*** Three to five days before farrowing, add to the concentrate mixture 10 to 20% wheat bran, oats, or alfalfa meal. A combination of the three feeds will also do well. These feeds are high in fiber and tend to have a laxative effect on the sow. The recommended feeding level is 8 to 10 pounds per day of this concentrate mixture for sows and 6 to 8 pounds for gilts. Feed only what the animals will clean up in 45 minutes after twice-daily feeding. Continue feeding this diet for 3 to 5 days after farrowing.

***During Lactation*** Self-feed a 14% crude protein diet high in energy and low in fiber.

### Market Swine

***Young Pigs*** Feed 18 to 20% crude protein concentrate as creep feed to pigs three to six weeks of age. At least half the grain in the diet should be corn. Antibiotic in the diet should be 100 to 200 grams per ton of feed.

***Growing Pigs*** ***To 75 pounds*** - The diet should contain 16% crude protein. A mixture of corn with a concentrate which supplies enough of the essential amino acids is recommended for self-feeding. The amount of antibiotic required varies from 5 to 100 grams per ton of feed.

***Finishing Market Swine*** ***75-125 pounds*** - The diet should contain 15% crude protein for self-feeding. If an antibiotic is used, supply 20 to 50 grams per ton of feed.

***125 pounds to market*** - The diet should contain 12 to 14% crude protein for self-feeding. If an antibiotic is used, supply 20 to 50 grams per ton of feed. If market swine are hand fed, feed 4 to 4.5% of their body weight per day.

Swine weighing 50 to 200 pounds on full feed should have an average daily gain of 1 1/2 pounds or more. They require:

- ***up to 100 pounds live weight*** - 5 to 6 pounds of feed per day per 100 pounds live weight.
- ***from 100 pounds to finished weight (220 pounds)*** - 4 pounds of feed per day per 100 pounds live weight.
- a calcium: phosphorus ratio for grain-soybean meal diets of between 1:1 and 1.5:1.

Average feed efficiency for finishing pigs from 40 to 220 pounds is 350 pounds of feed to produce 100 pounds of gain. Lean, efficient, well-managed grower-finisher pigs can do even better. A feed efficiency goal of 100 pounds of gain from 300 pounds of feed can be expected.

When formulating a swine diet with a premix, allow 2 1/2 to 3% for this mineral-vitamin-antimicrobial mixture.

## NUTRIENT REQUIREMENT TABLE FOR SWINE

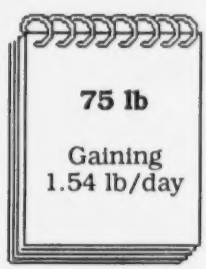
The table we will use to determine the energy and nutrient requirements of swine is **Appendix Table 5 NR, *Nutrient Requirements of Swine Allowed Feed Ad Libitum*** *(90% dry matter)*. This table can be used for pigs weighing from 2 pounds and gaining about 0.44 pound per day, to 240 pounds and gaining about 1.8 pounds per day. The nutrients required are given on a 90% dry matter basis.

## EXAMPLE DIET FOR SWINE

### For Growing and Finishing Swine

Most swine diets are formulated in one of three ways.

1. Combine corn and/or other grains with a complete protein supplement. The protein supplement would contain a vitamin-mineral premix in addition to the protein source.
2. Combine corn and/or other grains with soybean meal and a complete vitamin-mineral premix.
3. Combine corn and/or other grains with soybean meal, a vitamin premix, trace minerals, salt, and sources for both calcium and phosphorus.




Method 1 will be used in the following example. We will balance a diet to be fed to a 75-pound pig that is expected to gain an average 1.54 pounds per day.

***STEP 1*** **Identify the feedstuffs available for feeding a 75-pound pig.** For this exercise the principal feedstuffs will be:

corn (grain, shelled)
protein supplement with vitamins and minerals

***STEP 2*** **Determine the nutrient composition of the selected feedstuffs.** In this example we will be using as-fed nutrient composition figures rather than 100% dry matter. The as-fed figures are shown in Worksheet A, Sample 1 (below). (Appendix Table 1C, *Composition of Selected Feeds and Their Energy Values,* is the source of this information.) The analysis for the supplement would be provided on the feed tag. These figures, too, are shown in the worksheet sample below.

**Worksheet A, Sample 1 Feeds Available and Their Composition** (as-fed basis)

Date 4/4/92 Prepared by *Jane Doe*

| Feeds available | As fed lb | DM % | Energy Mcal/lb* | | | | CP % | Ca % | P % | Lysine for Swine % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | NEM | NEG | NEL | ME | | | | |
| *Corn (shelled)* | | 89 | | | | | 9.6 | 0.03 | 0.26 | 0.25 |
| *Protein supplement* | | 90 | | | | | 34.0 | 4.0 | 1.8 | 2.5 |
| | | | | | | | | | | |
| | | | | | | | | | | |

***STEP 3*** **Identify the life cycle information of the pig being fed.** In this case, information is needed concerning weight, daily gain, and particular use (growing-finishing). This information is recorded at the top of **Worksheet B, Sample 5** (page 215).

***STEP 4*** **Identify the nutrient requirements for this pig.** The information at the top of page 216 is from Appendix Table 5 NR and has been transferred to Worksheet B, Sample 5. Note that all swine nutrient requirements are based on air-dry feed (90% dry matter).

***STEP 5*** **Consider the following guidelines** when feeding the 75-pound growing pig.

- The diet should contain 15% protein for self-feeding.
- Corn and soybean meal are both high in metabolizable energy. (SBM is commonly used as a major ingredient in protein supplements.) Any combination of these two will satisfy energy requirements. Therefore there is no need to balance for it.
- Lysine is a very important amino acid in swine nutrition. Corn, a very common feedstuff used in feeding swine, has low levels of lysine. Because of this, the lysine content of the feed must also be balanced.

*(continued)*

## Worksheet B, Sample 5 Diet Evaluation

**Date** 4/4/92 **Prepared by** *Jane Doe* **Species** *Swine* **Weight** 75 lb

**Type of animal or use** *Growing - finishing pig* **Special considerations** *Gaining 1.54 lb/day Medium frame*

| | As fed % | DM % | Energy Mcal* | | | | For swine change lb to % | | | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NEM | NEG | NEL | ME | CP % | Ca % | P % | Lysine for Swine % | | |
| Daily nutrient requirements | | | | | | | 15 | 0.60 | 0.50 | 0.75 | | |
| Feedstuffs in diet | | | | | | | | | | | | |
| *Corn (shelled)* | 77.9 | | | | | | | 0.02 | 0.20 | 0.19 | | |
| *Protein supplement* | 22.1 | | | | | | | 0.88 | 0.40 | 0.55 | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| Total in diet | 100% | | | | | | 15 | 0.90 | 0.60 | 0.74 | | |
| Oversupply | | | | | | | | 0.30 | 0.10 | - - | | |
| Undersupply | | | | | | | | - - | - - | 0.01 | | |

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* Use the appropriate energy designation for the livestock to be fed.

*(Excerpt from Appendix Table 5 NR)*

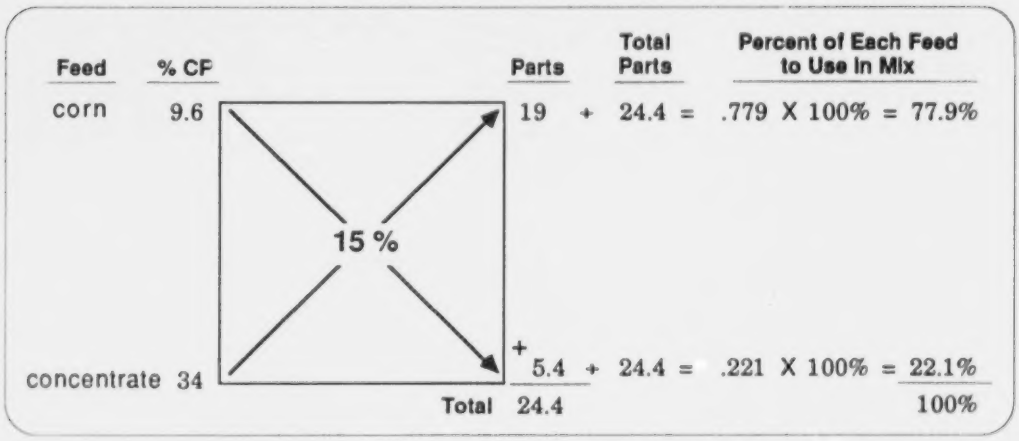
| Intake and Performance Levels | Swine Liveweight (lb) 2–10 | 11–21 | 22–43 | 44–109 | 110–240 |
|---|---|---|---|---|---|
| Expected weight gain (lb/day) | 0.44 | 0.55 | 1.0 | 1.54 | 1.8 |
| Expected feed intake (lb/day) | 0.55 | 1.01 | 2.1 | 4.2 | 6.9 |
| Expected efficiency (gain/feed) | 0.80 | 0.543 | 0.474 | 0.368 | 0.264 |
| Expected efficiency (feed/gain) | 1.25 | 1.84 | 2.11 | 2.71 | 3.79 |
| Metabolizable energy intake (Mcal/day) | 805 | 1,490 | 3,090 | 6,200 | 10,185 |
| Energy concentration (Mcal ME/lb diet) | 1.46 | 1.47 | 1.474 | 1.478 | 1.485 |
| Protein | 24% | 20% | 18% | 15% | 13% |
| | **Requirement (% in diet)*** | | | | |
| NUTRIENT | | | | | |
| Indispensable amino acids (%) | | | | | |
| Arginine | 0.60 | 0.50 | 0.40 | 0.25 | 0.10 |
| Histidine | 0.36 | 0.31 | 0.25 | 0.22 | 0.18 |
| Isoleucine | 0.76 | 0.65 | 0.53 | 0.46 | 0.38 |
| Leucine | 1.00 | 0.85 | 0.70 | 0.60 | 0.50 |
| Lysine | 1.40 | 1.15 | 0.95 | 0.75 | 0.60 |
| Methionine + cystine | 0.68 | 0.58 | 0.48 | 0.41 | 0.34 |
| Phenylalanine + tyrosine | 1.10 | 0.94 | 0.77 | 0.66 | 0.55 |
| Threonine | 0.80 | 0.68 | 0.56 | 0.48 | 0.40 |
| Tryptophan | 0.20 | 0.17 | 0.14 | 0.12 | 0.10 |
| Valine | 0.80 | 0.68 | 0.56 | 0.48 | 0.40 |
| Linoleic acid (%) | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Mineral elements | | | | | |
| Calcium (%) | 0.90 | 0.80 | 0.70 | 0.60 | 0.50 |
| Phosphorus, total (%) | 0.70 | 0.65 | 0.60 | 0.50 | 0.40 |
| Phosphorus, available (%) | 0.55 | 0.40 | 0.32 | 0.23 | 0.15 |
| Sodium (%) | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Chlorine (%) | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Magnesium (%) | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Potassium (%) | 0.30 | 0.28 | 0.26 | 0.23 | 0.17 |
| Copper (mg or ppm) | 6.0 | 6.0 | 5.0 | 4.0 | 3.0 |
| Iodine (mg or ppm) | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| Iron (mg or ppm) | 100 | 100 | 80 | 60 | 40 |

- Swine rations are calculated using the *as-fed* moisture percent figures. The 100% dry matter figures will not be used here with swine.
- The protein supplement needs to be selected for growing pigs in the 44- to 109-pound weight range. In addition to protein, this supplement will provide minerals, vitamins, amino acids, and antibiotics to the diet.

*STEP 6* **Formulate the diet.** The steps to be used in balancing this diet are as follows:

**A.** Balance the diet for protein using the square method.
**B.** Calculate calcium and phosphorus amounts.
**C.** Check calcium to phosphorus ratio.
**D.** Calculate amount of lysine in diet.
**E.** Calculate pounds of each feed to use in mix.

**A.** Using the square method, balance a diet for crude protein.




**B.** Check for appropriate calcium and phosphorus amounts in the diet.

| Ca | % of feed in diet | | amount Ca in feed | % Ca provided by feed in diet |
|---|---|---|---|---|
| corn | 77.9% | X | 0.0003 Ca | = 0.02% in the diet |
| supplement | 22.1% | X | 0.04 Ca | = 0.88% in the diet |
| | | | | Total 0.90 % in the diet |

➪ 0.90% **Ca** *provided* – 0.60% *required* = 0.30% *oversupply*

| P | % of feed in diet | | amount P in feed | % P provided by feed in diet |
|---|---|---|---|---|
| corn | 77.9% | X | 0.0026 P | = 0.20% in the diet |
| supplement | 22.1% | X | 0.018 P | = 0.40% in the diet |
| | | | | Total 0.60% in the diet |

➪ 0.60% **P** *provided* – 0.50% *required* = 0.10% *oversupply*

**C.** Check calcium to phosphorus ratio by dividing % Ca by % P.

.90% Ca : 0.60% P

1.5 : 1

We have maintained the calcium to phosphorus ratio within the limit of 1.5 : 1.

**D.** Check for correct amount of lysine in the diet.

| | % of feed in diet | | amount lysine in feed | | % lysine provided by feed in diet |
|---|---|---|---|---|---|
| corn | 77.9% | X | 0.0025 | = | 0.19% in the diet |
| supplement | 22.1% | X | 0.025 | = | 0.55% in the diet |
| | | | | Total | 0.74% in the diet |

☞ 0.74% *lysine provided* – 0.75% *lysine required* = 0.01% *undersupply*

The diet for the 75-pound pig has now been balanced for a 15% crude protein level. Calcium and phosphorus have been found to be present at a ratio of 1.5: 1. Lysine is present in adequate amounts.

**E.** Calculate the number of pounds of each feed to use in the mix.

For 4.2 pounds of feed for one 75-pound pig:

| lb of feed | | % of feed in diet | | |
|---|---|---|---|---|
| 4.2 | X | .779 corn | = | 3.3 lb corn |
| 4.2 | X | .221 suppl. | = | 0.9 lb supplement |

For one ton of this diet:

| | | | | |
|---|---|---|---|---|
| 2000 lb | X | .779 corn | = | 1558 lb corn |
| 2000 lb | X | .221 suppl. | = | 442 lb supplement |
| | | | Total | 2000 lb |

# COMPARING COSTS OF DIETS

The purpose of comparing costs of diets is to select a diet that will supply the needed nutrients at the ***least cost***. Nutrient content and cost should be compared at the same time. Worksheet C, Sample 1, ***Comparing Nutrient Content and Cost of Diets for Cattle and Sheep*** (page 221) shows such comparisons. After a comparison of nutrient content and cost, the least costly diet is selected and referred to as the ***most economical*** (as long as each of the diets compared supplies enough of the required nutrients). It is also important to remember, when comparing diets, that factors besides the actual cost of each feedstuff should also be considered. The questions you need to consider are:

- Is each nutrient supplied in the required amount?
- Is the diet palatable enough that it will be eaten by the kind of livestock being fed?
- Are all feeds that compose the diet available?
- Have differences in feed preparation (grinding, mixing) been considered?
- Are the feed costs that are used up-to-date (current)? Feed costs change over short periods of time, even from week to week. It is useless to compare costs unless current prices are used.
- Are the recommended feeds affected by limitations in the quantity that can be fed?

The nutrient content and costs of two diets are used as examples in Worksheet C, Sample 1 as follows:

- The crude protein percentage is almost the same for each diet: Diet 1- 19.2%; Diet 2- 19.7%.
- Diet 2 contains 51 pounds more dry matter per ton.
- Diet 2 contains 0.54 pound more calcium and 1.05 pounds more phosphorus per ton.
- Diet 1 contains 1.48 ME Mcal/lb DM and Diet 2 contains 1.66 ME Mcal/lb DM. Diet 2 thus supplies more energy.
- Diet 2 costs $24.18 per ton ***more*** than Diet 1.
- Grinding costs for each diet would be almost the same because Diet 1 has 1,600 pounds of grain (corn) to be ground and Diet 2 has 1,540 pounds of grain (corn and oats) to be ground.
- The cost per pound of CP is:
  Diet 1 $ 0.376
  Diet 2 $ 0.427
- The cost per ME Mcal of energy is:
  Diet 1 $ 0.047
  Diet 2 $ 0.051

A blank Worksheet C is included on page 220 for your use in comparing the nutrient content and cost of the diets you will be formulating.

## Worksheet C
## Comparing Nutrient Content and Cost of Various Diets

Cost of Feed Materials per One Hundred Pounds (cwt)_____

| | Diets (per ton of feed) | Total Dry Matter (lb) | Crude Protein (lb) | ME M cal | Calcium (lb) | Phosphorus (lb) | Cost $ |
|---|---|---|---|---|---|---|---|
| DIET 1 | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | *Total of Diet 1* | | | | | | |
| DIET 2 | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | *Total of Diet 2* | | | | | | |
| DIET 3 | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | *Total of Diet 3* | | | | | | |
| DIET 4 | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | *Total of Diet 4* | | | | | | |

Comments:_____

## Worksheet C, Sample 1
## Comparing Nutrient Content and Cost of Diets for Cattle and Sheep

**Cost of Feed Materials per One Hundred Pounds (cwt)**

*Ear corn (farm price)* - $ 3.80 — *Soybean meal (44% protein)* - $ 15.65

*Oats (farm price)* - $ 7.05 — *Linseed meal (35% protein)* - $ 17.70

| | Diets (per ton of feed) | Total Dry Matter (lb) | Crude Protein (lb) | ME Mcal | Calcium (lb) | Phosphorus (lb) | Cost $ |
|---|---|---|---|---|---|---|---|
| DIET 1 | *1600 lb ear corn* | 1344 | 128 | 2083 | 0.64 | 3.52 | $ 60.80 |
| | *400 lb soybean meal* | 360 | 200 | 536 | 1.28 | 2.68 | 62.60 |
| | | | (19.2%) | 1.48 ME Mcal/lb DM | | | |
| | ***Total of Diet 1*** | 1704 | 328 | 2619 | 1.92 | 6.20 | 123.40 |
| DIET 2 | *1160 lb ear corn* | 997 | 93 | 1798 | 0.46 | 2.55 | 44.08 |
| | *380 lb oats* | 342 | 50 | 462 | 0.34 | 1.25 | 26.79 |
| | *230 lb soybean meal* | 207 | 115 | 343 | 0.74 | 1.54 | 36.00 |
| | *230 lb linseed meal* | 209 | 88 | 315 | 0.92 | 1.91 | 40.71 |
| | | | (19.7%) | 1.66 ME Mcal/lb DM | | | |
| | ***Total of Diet 2*** | 1755 | 346 | 2918 | 2.46 | 7.25 | 147.58 |
| DIET 3 | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | ***Total of Diet 3*** | | | | | | |
| DIET 4 | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | ***Total of Diet 4*** | | | | | | |

**Comments:** *From a nutrient standpoint, either diet is suitable. The digestible protein % is almost the same for each diet. Diet 2 contains slightly more dry matter and minerals. Diet 2 contains slightly more metabolizable energy per pound of DM. Diet 2 costs $24.18 per ton more than Diet 1. The cost of grinding grain is the same for each diet.*

**Important biological concepts to learn from Unit 6:**

★ There are significant differences in the nutritional requirements and diets from one species of livestock to another.

★ Both nutrient requirements and feeding guidelines for a particular animal are important to know before formulating a balanced diet to feed it.

★ When a balanced diet is being formulated for an animal, the feedstuffs included in the diet must provide all the energy and nutrients in the amounts required to maintain the animal's body and to provide for the production desired from the animal. Either undersupply or oversupply of any of the nutrients will be costly to the producer.

## FINAL REVIEW

After studying Unit 6, "Feeding Guidelines and Example Diet Formulations," you should be able to answer and discuss the following.

1. Choose one livestock species and describe a balanced diet for it.

2. On a pound-for-pound dry-matter basis, what would be the nutritional advantage of corn silage over hay? *(pages 180-181)*

3. How can the quality of roughage in a dairy cow's diet affect the selection of the concentrate part of her diet? *(pages 187-189)*

4. Why are young dairy calves unable to consume large amounts of roughage? *(page 191)*

5. In formulating balanced diets for livestock, why is it important to have some knowledge of the functioning of the animals' digestive tract? *(Unit 1)*

6. Why is it important to have some knowledge of the nature of the food nutrients required by your livestock? *(Unit 2)*

7. Why is it important to have some knowledge of the nutrient requirements of livestock during their different life cycle stages? *(Unit 3)*

8. What do you need to know about the various feedstuffs available to you for feeding your livestock? *(Unit 4)*

9. Outline the steps that may be followed in balancing the diet for your livestock. *(Unit 5, pages 171-174)*

10. Formulate balanced diets for the livestock in your supervised agricultural experience program following the procedures described in this unit.

# APPENDIX

## Appendix Table 1C COMPOSITION OF SELECTED FEEDS

Data expressed *as-fed* and *dry* (100% dry matter)

| Entry number | Feed Name Description | Dry Matter | RUMINANTS ME Mcal/ | | NEM Mcal/ | | NEG Mcal/ | | DAIRY NEL Mcal/ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | % | kg | lb | kg | lb | kg | lb | kg | lb |
| | | | DRY ROUGHAGES | | | | | | | |
| | ***Alfalfa hay (North)*** | | | | | | | | | |
| 01 | Sun-cured, late vege- | 90 | 2.11 | 0.96 | 1.24 | 0.56 | 0.67 | 0.30 | 1.28 | 0.58 |
| 02 | tative | 100 | 2.36 | 1.07 | 1.39 | 0.63 | 0.75 | 0.34 | 1.42 | 0.64 |
| 03 | Sun-cured, early bloom | 90 | 2.00 | 0.91 | 1.18 | 0.54 | 0.59 | 0.27 | 1.22 | 0.55 |
| 04 | | 100 | 2.22 | 1.01 | 1.31 | 0.59 | 0.65 | 0.29 | 1.35 | 0.61 |
| 05 | Sun-cured, midbloom | 90 | 1.92 | 0.87 | 1.13 | 0.51 | 0.52 | 0.24 | 1.17 | 0.53 |
| 06 | | 100 | 2.13 | 0.97 | 1.26 | 0.57 | 0.58 | 0.26 | 1.30 | 0.59 |
| 07 | Sun-cured, full bloom | 90 | 1.80 | 0.82 | 1.07 | 0.49 | 0.43 | 0.20 | 1.11 | 0.50 |
| 08 | | 100 | 2.00 | 0.91 | 1.19 | 0.54 | 0.58 | 0.26 | 1.23 | 0.56 |
| 09 | Sun-cured, mature | 91 | 1.62 | 0.73 | 0.98 | 0.44 | 0.25 | 0.11 | 1.01 | 0.46 |
| 10 | | 100 | 1.78 | 0.81 | 1.07 | 0.49 | 0.28 | 0.13 | 1.11 | 0.50 |
| | ***Brome hay*** | | | | | | | | | |
| 11 | Sun-cured, late vege- | 88 | 2.26 | 1.03 | 1.34 | 0.61 | 0.80 | 0.36 | 1.36 | 0.62 |
| 12 | tative | 100 | 2.58 | 1.17 | 1.52 | 0.69 | 0.91 | 0.41 | 1.55 | 0.70 |
| | ***Clover, Red, hay*** | | | | | | | | | |
| 13 | Sun-cured | 89 | 1.77 | 0.80 | 1.05 | 0.48 | 0.42 | 0.19 | 1.09 | 0.49 |
| 14 | | 100 | 2.00 | 0.91 | 1.19 | 0.54 | 0.47 | 0.21 | 1.23 | 0.56 |
| | ***Clover, Ladino, hay*** | | | | | | | | | |
| 15 | Sun-cured | 90 | 2.19 | 0.99 | 1.29 | 0.59 | 0.73 | 0.33 | 1.32 | 0.60 |
| 16 | | 100 | 2.45 | 1.11 | 1.44 | 0.65 | 0.82 | 0.37 | 1.47 | 0.67 |
| | ***Oats*** | | | | | | | | | |
| 17 | Hay, sun-cured | 91 | 2.07 | 0.94 | 1.22 | 0.55 | 0.63 | 0.29 | 1.26 | 0.57 |
| 18 | | 100 | 2.27 | 1.03 | 1.33 | 0.60 | 0.69 | 0.31 | 1.38 | 0.63 |
| 19 | Straw | 92 | 1.64 | 0.74 | 0.99 | 0.45 | 0.25 | 0.11 | 1.02 | 0.46 |
| 20 | | 100 | 1.78 | 0.81 | 1.07 | 0.48 | 0.28 | 0.13 | 1.11 | 0.50 |
| | ***Orchardgrass hay*** | | | | | | | | | |
| 21 | Sun-cured (late bloom) | 91 | 1.77 | 0.80 | 1.05 | 0.48 | 0.39 | 0.18 | 1.09 | 0.49 |
| 22 | | 100 | 1.96 | 0.89 | 1.16 | 0.53 | 0.43 | 0.20 | 1.20 | 0.54 |
| | ***Timothy hay*** | | | | | | | | | |
| 23 | Sun-cured, late vege- | 89 | 2.42 | 1.10 | 1.44 | 0.65 | 0.89 | 0.40 | 1.45 | 0.66 |
| 24 | tative | 100 | 2.71 | 1.23 | 1.61 | 0.73 | 1.00 | 0.45 | 1.62 | 0.73 |
| 25 | Sun-cured, early bloom | 90 | 2.23 | 1.01 | 1.31 | 0.59 | 0.76 | 0.34 | 1.34 | 0.61 |
| 26 | | 100 | 2.49 | 1.13 | 1.47 | 0.67 | 0.85 | 0.39 | 1.50 | 0.68 |
| 27 | Sun-cured, midbloom | 89 | 2.01 | 0.91 | 1.19 | 0.54 | 0.61 | 0.28 | 1.22 | 0.55 |
| 28 | | 100 | 2.27 | 1.03 | 1.33 | 0.60 | 0.69 | 0.31 | 1.38 | 0.63 |
| 29 | Sun-cured, full bloom | 89 | 1.89 | 0.86 | 1.12 | 0.51 | 0.52 | 0.24 | 1.15 | 0.52 |
| 30 | | 100 | 2.13 | 0.97 | 1.26 | 0.57 | 0.58 | 0.26 | 1.30 | 0.59 |
| 31 | Sun-cured, late bloom | 88 | 1.81 | 0.82 | 1.07 | 0.49 | 0.45 | 0.20 | 1.11 | 0.50 |
| 32 | | 100 | 2.04 | 0.93 | 1.21 | 0.55 | 0.51 | 0.23 | 1.25 | 0.57 |

## AND THEIR ENERGY VALUES

| Entry number | HORSES ME Mcal/ kg | HORSES ME Mcal/ lb | SWINE ME kcal/ kg | SWINE ME kcal/ lb | Lysine % | Crude Protein % | Calcium (Ca) % | Phosphorus (P) % | Crude Fiber % | Ash % |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Alfalfa hay (North)*** | | | | | | | | | | |
| 01 | 1.58 | 0.72 | - - | - - | 0.99 | 17.9 | 1.38 | 0.26 | 19.7 | 8.3 |
| 02 | 1.76 | 0.80 | - - | - - | 1.10 | 20.0 | 1.54 | 0.29 | 22.0 | 9.2 |
| 03 | 1.50 | 0.68 | - - | - - | 0.81 | 16.2 | 1.27 | 0.20 | 20.7 | 8.6 |
| 04 | 1.67 | 0.76 | - - | - - | 0.90 | 18.0 | 1.41 | 0.22 | 23.0 | 9.6 |
| 05 | 1.39 | 0.63 | - - | - - | - - | 15.3 | 1.27 | 0.22 | 23.4 | 8.2 |
| 06 | 1.55 | 0.70 | - - | - - | - - | 17.0 | 1.41 | 0.24 | 26.0 | 9.1 |
| 07 | 1.46 | 0.66 | - - | - - | 0.78 | 13.5 | 1.13 | 0.20 | 26.1 | 8.0 |
| 08 | 1.62 | 0.73 | - - | - - | 0.87 | 15.0 | 1.25 | 0.22 | 29.0 | 8.9 |
| 09 | 1.38 | 0.63 | - - | - - | - - | 11.7 | 1.03 | 0.17 | 34.4 | 6.9 |
| 10 | 1.51 | 0.68 | - - | - - | - - | 12.9 | 1.13 | 0.18 | 37.7 | 7.5 |
| ***Brome hay*** | | | | | | | | | | |
| 11 | 1.37 | 0.62 | - - | - - | - - | 14.0 | 0.28 | 0.33 | 26.3 | 8.3 |
| 12 | 1.56 | 0.71 | - - | - - | - - | 16.0 | 0.32 | 0.37 | 30.0 | 9.4 |
| ***Clover, Red, hay*** | | | | | | | | | | |
| 13 | 1.45 | 0.66 | - - | - - | - - | 14.2 | 1.35 | 0.22 | 25.5 | 7.5 |
| 14 | 1.63 | 0.74 | - - | - - | - - | 16.0 | 1.53 | 0.25 | 28.8 | 8.5 |
| ***Clover, Ladino, hay*** | | | | | | | | | | |
| 15 | 1.49 | 0.68 | - - | - - | 1.08 | 19.7 | 1.21 | 0.28 | 19.1 | 9.0 |
| 16 | 1.66 | 0.75 | - - | - - | 1.20 | 22.0 | 1.35 | 0.31 | 21.2 | 10.1 |
| ***Oats*** | | | | | | | | | | |
| 17 | 1.42 | 0.64 | - - | - - | - - | 8.5 | 0.22 | 0.20 | 27.8 | 7.0 |
| 18 | 1.55 | 0.70 | - - | - - | - - | 9.3 | 0.24 | 0.22 | 30.4 | 7.6 |
| 19 | 1.45 | 0.66 | - - | - - | - - | 4.1 | 0.22 | 0.06 | 37.3 | 7.2 |
| 20 | 1.58 | 0.72 | - - | - - | - - | 4.4 | 0.24 | 0.06 | 40.5 | 7.8 |
| ***Orchardgrass hay*** | | | | | | | | | | |
| 21 | 1.45 | 0.66 | - - | - - | - - | 7.6 | 0.35 | 0.32 | 33.6 | 9.2 |
| 22 | 1.61 | 0.73 | - - | - - | - - | 8.4 | 0.39 | 0.35 | 37.1 | 10.1 |
| ***Timothy hay*** | | | | | | | | | | |
| 23 | 1.82 | 0.83 | - - | - - | - - | 15.2 | 0.59 | 0.30 | 24.1 | 6.3 |
| 24 | 2.03 | 0.92 | - - | - - | - - | 17.0 | 0.66 | 0.34 | 27.0 | 7.1 |
| 25 | 1.68 | 0.76 | - - | - - | - - | 13.4 | 0.48 | 0.22 | 25.1 | 5.1 |
| 26 | 1.87 | 0.85 | - - | - - | - - | 15.0 | 0.53 | 0.25 | 28.0 | 5.7 |
| 27 | 1.64 | 0.74 | - - | - - | - - | 8.1 | 0.43 | 0.20 | 27.6 | 5.6 |
| 28 | 1.84 | 0.83 | - - | - - | - - | 9.1 | 0.48 | 0.22 | 31.0 | 6.3 |
| 29 | 1.29 | 0.59 | - - | - - | - - | 7.2 | 0.38 | 0.18 | 28.4 | 4.6 |
| 30 | 1.46 | 0.66 | - - | - - | - - | 8.1 | 0.43 | 0.20 | 32.0 | 5.2 |
| 31 | 1.37 | 0.62 | - - | - - | - - | 6.9 | 0.34 | 0.16 | 28.7 | 4.8 |
| 32 | 1.55 | 0.70 | - - | - - | - - | 7.8 | 0.38 | 0.18 | 32.5 | 5.4 |

*(continued)*

## Appendix Table 1C COMPOSITION OF SELECTED FEEDS

| Entry number | Feed Name Description | Dry Matter | RUMINANTS | | | | | | DAIRY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ME Mcal/ | | NEM Mcal/ | | NEG Mcal/ | | NEL Mcal/ | |
| | | % | kg | lb | kg | lb | kg | lb | kg | lb |
| | ***Trefoil, Birdsfoot, hay*** | | | | | | | | | |
| 33 | Sun-cured | 92 | 2.01 | 0.91 | 1.18 | 0.54 | 0.57 | 0.26 | 1.22 | 0.55 |
| 34 | | 100 | 2.18 | 0.99 | 1.28 | 0.58 | 0.62 | 0.28 | 1.33 | 0.60 |
| | ***Corn, Dent Yellow*** | | | | | | | | | |
| 35 | Aerial part with ears, sun-cured (Fodder) | 81 | 1.99 | 0.90 | 1.17 | 0.53 | 0.66 | 0.30 | 1.20 | 0.54 |
| 36 | | 100 | 2.45 | 1.11 | 1.44 | 0.65 | 0.82 | 0.37 | 1.47 | 0.67 |
| 37 | Aerial part with ears, sun-cured, mature (Fodder) | 82 | 2.15 | 0.98 | 1.27 | 0.58 | 0.77 | 0.35 | 1.29 | 0.59 |
| 38 | | 100 | 2.62 | 1.19 | 1.55 | 0.70 | 0.94 | 0.43 | 1.57 | 0.71 |
| 39 | Aerial part without ears without husks, sun-cured (Stover) (Straw) | 85 | 1.85 | 0.84 | 1.09 | 0.49 | 0.53 | 0.24 | 1.13 | 0.51 |
| 40 | | 100 | 2.18 | 0.99 | 1.28 | 0.58 | 0.62 | 0.28 | 1.33 | 0.60 |
| | ***Wheat*** | | | | | | | | | |
| 41 | Straw | 89 | 1.34 | 0.61 | 0.85 | 0.39 | 0.01 | 0.005 | 0.85 | 0.39 |
| 42 | | 100 | 1.51 | 0.68 | 0.96 | 0.44 | 0.01 | 0.005 | 0.96 | 0.44 |
| | | | | | SILAGES | | | | | |
| | ***Alfalfa*** | | | | | | | | | |
| 43 | Wilted silage, early bloom | 35 | 0.77 | 0.35 | 0.45 | 0.20 | 0.23 | 0.10 | 0.47 | 0.21 |
| 44 | | 100 | 2.22 | 1.01 | 1.31 | 0.59 | 0.65 | 0.29 | 1.35 | 0.61 |
| 45 | Wilted silage, midbloom | 38 | 0.81 | 0.37 | 0.48 | 0.22 | 0.22 | 0.10 | 0.50 | 0.23 |
| 46 | | 100 | 2.13 | 0.97 | 1.26 | 0.57 | 0.58 | 0.26 | 1.30 | 0.59 |
| 47 | Wilted silage, full bloom | 45 | 0.90 | 0.41 | 0.53 | 0.24 | 0.21 | 0.10 | 0.55 | 0.25 |
| 48 | | 100 | 2.00 | 0.91 | 1.19 | 0.54 | 0.47 | 0.21 | 1.23 | 0.56 |
| | ***Corn, Dent Yellow*** | | | | | | | | | |
| 49 | Silage | 30 | 0.79 | 0.36 | 0.47 | 0.21 | 0.28 | 0.13 | 0.47 | 0.21 |
| 50 | | 100 | 2.62 | 1.19 | 1.55 | 0.70 | 0.94 | 0.43 | 1.57 | 0.71 |
| 51 | Silage, few ears | 29 | 0.68 | 0.31 | 0.40 | 0.18 | 0.21 | 0.10 | 0.41 | 0.19 |
| 52 | | 100 | 2.31 | 1.05 | 1.36 | 0.62 | 0.72 | 0.34 | 1.40 | 0.64 |
| 53 | Silage, well eared | 33 | 0.89 | 0.40 | 0.53 | 0.24 | 0.32 | 0.15 | 0.53 | 0.24 |
| 54 | | 100 | 2.67 | 1.21 | 1.58 | 0.72 | 0.97 | 0.44 | 1.60 | 0.73 |
| 55 | Silage, milk stage | 22 | 0.54 | 0.24 | 0.32 | 0.15 | 0.18 | 0.08 | 0.33 | 0.15 |
| 56 | | 100 | 2.45 | 1.11 | 1.44 | 0.65 | 0.82 | 0.37 | 1.47 | 0.67 |
| 57 | Silage, dough stage | 26 | 0.70 | 0.32 | 0.41 | 0.19 | 0.25 | 0.11 | 0.42 | 0.19 |
| 58 | | 100 | 2.62 | 1.19 | 1.55 | 0.70 | 0.94 | 0.43 | 1.57 | 0.71 |
| | ***Sorghum*** | | | | | | | | | |
| 59 | Silage | 30 | 0.66 | 0.30 | 0.39 | 0.18 | 0.19 | 0.09 | 0.40 | 0.18 |
| 60 | | 100 | 2.22 | 1.01 | 1.31 | 0.59 | 0.65 | 0.29 | 1.35 | 0.61 |
| | ***Timothy*** | | | | | | | | | |
| 61 | Silage, early bloom | 36 | 0.81 | 0.37 | 0.48 | 0.22 | 0.24 | 0.11 | 0.49 | 0.22 |
| 62 | | 100 | 2.22 | 1.01 | 1.31 | 0.59 | 0.65 | 0.29 | 1.35 | 0.61 |

## AND THEIR ENERGY VALUES *(page 2)*

| Entry number | HORSES ME Mcal/ kg | HORSES ME Mcal/ lb | SWINE ME kcal/ kg | SWINE ME kcal/ lb | Lysine % | Crude Protein % | Calcium (Ca) % | Phosphorus (P) % | Crude Fiber % | Ash % |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Trefoil, Birdsfoot, hay*** | | | | | | | | | | |
| 33 | 1.49 | 0.68 | - - | - - | - - | 15.0 | 1.57 | 0.25 | 28.3 | 6.5 |
| 34 | 1.62 | 0.73 | - - | - - | - - | 16.3 | 1.70 | 0.27 | 30.7 | 7.0 |
| ***Corn, Dent Yellow*** | | | | | | | | | | |
| 35 | 1.22 | 0.55 | - - | - - | - - | 7.2 | 0.41 | 0.20 | 20.5 | 5.5 |
| 36 | 1.50 | 0.68 | - - | - - | - - | 8.9 | 0.50 | 0.25 | 25.2 | 6.8 |
| 37 | 1.17 | 0.53 | - - | - - | - - | 6.6 | - - | - - | 18.6 | 4.4 |
| 38 | 1.43 | 0.65 | - - | - - | - - | 8.0 | - - | - - | 22.6 | 5.4 |
| 39 | 1.07 | 0.49 | - - | - - | - - | 5.6 | 0.49 | 0.08 | 29.3 | 6.1 |
| 40 | 1.26 | 0.57 | - - | - - | - - | 6.6 | 0.57 | 0.10 | 34.4 | 7.2 |
| ***Wheat*** | | | | | | | | | | |
| 41 | 1.04 | 0.47 | - - | - - | - - | 3.2 | 0.16 | 0.04 | 36.9 | 6.9 |
| 42 | 1.17 | 0.53 | - - | - - | - - | 3.6 | 0.18 | 0.05 | 41.6 | 7.8 |
| SILAGES | | | | | | | | | | |
| ***Alfalfa*** | | | | | | | | | | |
| 43 | - - | - - | - - | - - | - - | 5.9 | - - | - - | 9.7 | 2.8 |
| 44 | - - | - - | - - | - - | - - | 17.0 | - - | - - | 28.0 | 8.2 |
| 45 | - - | - - | - - | - - | - - | 5.9 | 0.52 | 0.12 | 11.4 | 3.0 |
| 46 | - - | - - | - - | - - | - - | 15.5 | 1.33 | 0.30 | 30.0 | 7.9 |
| 47 | - - | - - | - - | - - | - - | 6.3 | - - | - - | 14.9 | 3.5 |
| 48 | - - | - - | - - | - - | - - | 14.0 | - - | - - | 33.2 | 7.7 |
| ***Corn, Dent Yellow*** | | | | | | | | | | |
| 49 | - - | - - | 896 | 406 | 0.13 | 2.5 | 0.09 | 0.08 | 7.5 | 1.7 |
| 50 | - - | - - | 2,981 | 1,352 | 0.44 | 8.3 | 0.29 | 0.26 | 25.1 | 5.5 |
| 51 | - - | - - | - - | - - | - - | 2.4 | 0.10 | 0.06 | 9.4 | 2.1 |
| 52 | - - | - - | - - | - - | - - | 8.4 | 0.34 | 0.19 | 32.3 | 7.2 |
| 53 | - - | - - | - - | - - | - - | 2.7 | 0.08 | 0.07 | 7.9 | 1.5 |
| 54 | - - | - - | - - | - - | - - | 8.1 | 0.23 | 0.22 | 23.7 | 4.5 |
| 55 | - - | - - | - - | - - | - - | 2.0 | 0.09 | 0.07 | 6.8 | 1.2 |
| 56 | - - | - - | - - | - - | - - | 8.9 | 0.41 | 0.29 | 30.5 | 5.2 |
| 57 | - - | - - | - - | - - | - - | 2.1 | 0.07 | 0.05 | 6.5 | 1.2 |
| 58 | - - | - - | - - | - - | - - | 7.8 | 0.27 | 0.19 | 24.5 | 4.7 |
| ***Sorghum*** | | | | | | | | | | |
| 59 | - - | - - | 682 | 309 | - - | 2.2 | 0.10 | 0.06 | 8.2 | 2.6 |
| 50 | - - | - - | 2,306 | 1,046 | - - | 7.5 | 0.35 | 0.21 | 27.9 | 8.7 |
| ***Timothy*** | | | | | | | | | | |
| 61 | - - | - - | - - | - - | - - | 3.7 | - - | - - | 12.8 | 2.5 |
| 62 | - - | - - | - - | - - | - - | 10.2 | - - | - - | 35.3 | 6.8 |

*(continued)*

## Appendix Table 1C COMPOSITION OF SELECTED FEEDS

| Entry number | Feed Name Description | Dry Matter | RUMINANTS | | | | | | DAIRY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ME Mcal/ | | NEM Mcal/ | | NEG Mcal/ | | NEL Mcal/ | |
| | | % | kg | lb | kg | lb | kg | lb | kg | lb |
| | ***Timothy** (continued)* | | | | | | | | | |
| 63 | Silage, full bloom | 36 | 0.78 | 0.35 | 0.46 | 0.21 | 0.22 | 0.10 | 0.47 | 0.21 |
| 64 | | 100 | 2.18 | 0.99 | 1.28 | 0.58 | 0.62 | 0.28 | 1.33 | 0.60 |
| 65 | Silage, milk stage | 42 | 0.85 | 0.39 | 0.50 | 0.23 | 0.21 | 0.10 | 0.52 | 0.24 |
| 66 | | 100 | 2.04 | 0.93 | 1.21 | 0.55 | 0.51 | 0.23 | 1.25 | 0.57 |
| | CONCENTRATES | | | | | | | | | |
| | ***Alfalfa Meal*** | | | | | | | | | |
| 67 | Dehy., 17% protein | 92 | 2.08 | 0.94 | 1.22 | 0.55 | 0.63 | 0.29 | 1.26 | 0.57 |
| 68 | | 100 | 2.27 | 1.03 | 1.33 | 0.60 | 0.69 | 0.31 | 1.38 | 0.63 |
| | ***Barley*** | | | | | | | | | |
| 69 | Grain | 88 | 2.90 | 1.32 | 1.76 | 0.80 | 1.19 | 0.54 | 1.71 | 0.78 |
| 70 | | 100 | 3.29 | 1.49 | 2.00 | 0.91 | 1.35 | 0.61 | 1.94 | 0.88 |
| | ***Beet, Sugar*** | | | | | | | | | |
| 71 | Pulp, dehy. | 91 | 2.58 | 1.17 | 1.54 | 0.70 | 0.98 | 0.44 | 1.54 | 0.70 |
| 72 | | 100 | 2.85 | 1.29 | 1.70 | 0.77 | 1.08 | 0.49 | 1.69 | 0.77 |
| 73 | Pulp, wet | 11 | 0.33 | 0.15 | 0.20 | 0.09 | 0.13 | 0.06 | 0.20 | 0.09 |
| 74 | | 100 | 3.02 | 1.37 | 1.82 | 0.83 | 1.19 | 0.54 | 1.79 | 0.81 |
| | ***Molasses*** | | | | | | | | | |
| 75 | Beet, sugar | 78 | 2.38 | 1.08 | 1.44 | 0.65 | 0.95 | 0.43 | 1.41 | 0.64 |
| 76 | | 100 | 3.07 | 1.39 | 1.85 | 0.84 | 1.22 | 0.55 | 1.82 | 0.83 |
| 77 | Sugarcane, (Black strap) | 75 | 2.05 | 0.93 | 1.22 | 0.55 | 0.77 | 0.35 | 1.23 | 0.56 |
| 78 | | 100 | 2.76 | 1.25 | 1.64 | 0.74 | 1.03 | 0.47 | 1.64 | 0.74 |
| | ***Brewers Grains*** | | | | | | | | | |
| 79 | Dehy. | 92 | 2.46 | 1.12 | 2.10 | 0.95 | 1.25 | 0.57 | 1.47 | 0.67 |
| 80 | | 100 | 2.67 | 1.21 | 2.28 | 1.03 | 1.36 | 0.62 | 1.60 | 0.73 |
| 81 | Wet | 21 | 0.56 | 0.25 | 0.48 | 0.22 | 0.29 | 0.13 | 0.37 | 0.17 |
| 82 | | 100 | 2.67 | 1.21 | 2.28 | 1.03 | 1.36 | 0.62 | 1.60 | 0.73 |
| | ***Corn, Dent Yellow*** | | | | | | | | | |
| 83 | Ears, ground (Corn & | 87 | 2.81 | 1.27 | 1.70 | 0.77 | 1.14 | 0.52 | 1.66 | 0.75 |
| 84 | cob meal) | 100 | 3.25 | 1.47 | 1.97 | 0.89 | 1.32 | 0.60 | 1.91 | 0.87 |
| 85 | Grain (Shelled corn) | 89 | 3.03 | 1.37 | 1.85 | 0.84 | 1.26 | 0.57 | 1.78 | 0.81 |
| 86 | | 100 | 3.42 | 1.55 | 2.09 | 0.95 | 1.42 | 0.64 | 2.01 | 0.91 |
| 87 | Grain, high moisture | 77 | 2.80 | 1.27 | 1.73 | 0.78 | 1.18 | 0.54 | 1.64 | 0.74 |
| 88 | | 100 | 3.65 | 1.66 | 2.25 | 1.02 | 1.54 | 0.70 | 2.13 | 0.97 |
| 89 | Grits by-product | 90 | 3.37 | 1.53 | 2.09 | 0.95 | 1.43 | 0.65 | 1.97 | 0.90 |
| 90 | (Hominy feed) | 100 | 3.74 | 1.70 | 2.31 | 1.05 | 1.59 | 0.72 | 2.18 | 0.99 |
| | ***Oats*** | | | | | | | | | |
| 91 | Grain | 89 | 2.65 | 1.20 | 1.59 | 0.72 | 1.04 | 0.47 | 1.57 | 0.71 |
| 92 | | 100 | 2.98 | 1.35 | 1.79 | 0.81 | 1.17 | 0.53 | 1.77 | 0.80 |
| | ***Rye*** | | | | | | | | | |
| 93 | Grain | 88 | 2.88 | 1.31 | 1.75 | 0.79 | 1.18 | 0.54 | 1.70 | 0.77 |
| 94 | | 100 | 3.29 | 1.49 | 2.00 | 0.91 | 1.35 | 0.61 | 1.94 | 0.88 |

## AND THEIR ENERGY VALUES *(page 3)*

| Entry number | HORSES ME Mcal/ kg | HORSES ME Mcal/ lb | SWINE ME kcal/ kg | SWINE ME kcal/ lb | Lysine % | Crude Protein % | Calcium (Ca) % | Phosphorus (P) % | Crude Fiber % | Ash % |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***Timothy** (continued)* | | | | | | | | | |
| 63 | - - | - - | - - | - - | - - | 3.5 | 0.19 | 0.10 | 12.9 | 2.5 |
| 64 | - - | - - | - - | - - | - - | 9.7 | 0.55 | 0.29 | 36.3 | 6.9 |
| 65 | - - | - - | - - | - - | - - | 3.5 | - - | - - | 15.9 | 2.7 |
| 66 | - - | - - | - - | - - | - - | 8.4 | - - | - - | 38.4 | 6.6 |
| | ***Alfalfa Meal*** | | | | | | | | | |
| 67 | 1.47 | 0.67 | 1,196 | 543 | 0.85 | 17.3 | 1.40 | 0.23 | 24.0 | 9.7 |
| 68 | 1.60 | 0.73 | 1,304 | 591 | 0.93 | 18.9 | 1.52 | 0.25 | 26.2 | 10.6 |
| | ***Barley*** | | | | | | | | | |
| 69 | - - | - - | 2,910 | 1,320 | 0.39 | 11.9 | 0.04 | 0.34 | 5.0 | 2.3 |
| 70 | - - | - - | 3,299 | 1,496 | 0.44 | 13.5 | 0.05 | 0.38 | 5.7 | 2.6 |
| | ***Beet, Sugar*** | | | | | | | | | |
| 71 | - - | - - | 2,693 | 1,222 | 0.60 | 8.8 | 0.63 | 0.09 | 18.0 | 4.9 |
| 72 | - - | - - | 2,971 | 1,348 | 0.66 | 9.7 | 0.69 | 0.10 | 19.8 | 5.4 |
| 73 | - - | - - | - - | - - | - - | 1.2 | 0.10 | 0.01 | 3.1 | 0.5 |
| 74 | - - | - - | - - | - - | - - | 11.2 | 0.87 | 0.10 | 28.1 | 4.7 |
| | ***Molasses*** | | | | | | | | | |
| 75 | - - | - - | 2,333 | 1,058 | - - | 6.6 | 0.13 | 0.03 | - - | 8.8 |
| 76 | - - | - - | 3,002 | 1,362 | - - | 8.5 | 0.17 | 0.03 | - - | 11.3 |
| 77 | - - | - - | 2,199 | 997 | - - | 4.4 | 0.75 | 0.08 | - - | 9.8 |
| 78 | - - | - - | 2,951 | 1,339 | - - | 5.8 | 1.00 | 0.11 | - - | 13.1 |
| | ***Brewers Grains*** | | | | | | | | | |
| 79 | - - | - - | 2,285 | 1,036 | 0.88 | 27.1 | 0.30 | 0.51 | 13.2 | 3.6 |
| 80 | - - | - - | 2,482 | 1,126 | 0.95 | 29.4 | 0.33 | 0.55 | 14.4 | 3.9 |
| 81 | - - | - - | - - | - - | - - | 4.9 | 0.07 | 0.12 | 3.2 | 1.0 |
| 82 | - - | - - | - - | - - | - - | 23.2 | 0.33 | 0.55 | 15.3 | 4.8 |
| | ***Corn, Dent Yellow*** | | | | | | | | | |
| 83 | - - | - - | 2,779 | 1,261 | 0.17 | 7.8 | 0.06 | 0.24 | 8.2 | 1.7 |
| 84 | - - | - - | 3,212 | 1,457 | 0.20 | 9.0 | 0.07 | 0.27 | 9.4 | 1.9 |
| 85 | - - | - - | 3,300 | 1,497 | 0.25 | 9.6 | 0.03 | 0.26 | 2.6 | 1.3 |
| 86 | - - | - - | 3,724 | 1,689 | 0.28 | 10.9 | 0.03 | 0.29 | 2.9 | 1.5 |
| 87 | - - | - - | 2,713 | 1,231 | - - | 8.2 | 0.01 | 0.25 | 2.0 | 1.2 |
| 88 | - - | - - | 3,534 | 1,603 | - - | 10.7 | 0.02 | 0.32 | 2.6 | 1.6 |
| 89 | - - | - - | 3,382 | 1,534 | - - | 10.4 | 0.05 | 0.52 | 6.0 | 2.8 |
| 90 | - - | - - | 3,748 | 1,700 | - - | 11.5 | 0.05 | 0.57 | 6.7 | 3.1 |
| | ***Oats*** | | | | | | | | | |
| 91 | - - | - - | 2,676 | 1,214 | 0.39 | 11.8 | 0.07 | 0.33 | 10.8 | 3.1 |
| 92 | - - | - - | 3,012 | 1,366 | 0.44 | 13.3 | 0.07 | 0.38 | 12.1 | 3.4 |
| | ***Rye*** | | | | | | | | | |
| 93 | - - | - - | 2,911 | 1,320 | 0.42 | 12.1 | 0.06 | 0.32 | 2.2 | 1.6 |
| 94 | - - | - - | 3,327 | 1,509 | 0.48 | 13.8 | 0.07 | 0.37 | 2.5 | 1.9 |

*(continued)*

## Appendix Table 1C COMPOSITION OF SELECTED FEEDS

| Entry number | Feed Name Description | Dry Matter | RUMINANTS | | | | | | DAIRY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ME Mcal/ | | NEM Mcal/ | | NEG Mcal/ | | NEL Mcal/ | |
| | | % | kg | lb | kg | lb | kg | lb | kg | lb |
| | ***Sorghum*** | | | | | | | | | |
| 95 | Grain | 90 | 3.03 | 1.37 | 1.85 | 0.84 | 1.25 | 0.57 | 1.78 | 0.81 |
| 96 | | 100 | 3.38 | 1.53 | 2.06 | 0.93 | 1.40 | 0.64 | 1.99 | 0.90 |
| | ***Wheat*** | | | | | | | | | |
| 97 | Bran | 89 | 2.37 | 1.08 | 1.40 | 0.64 | 0.86 | 0.39 | 1.42 | 0.64 |
| 98 | | 100 | 2.67 | 1.21 | 1.58 | 0.72 | 0.97 | 0.44 | 1.60 | 0.73 |
| 99 | Grain | 89 | 3.08 | 1.40 | 1.89 | 0.86 | 1.28 | 0.58 | 1.81 | 0.82 |
| 100 | | 100 | 3.47 | 1.57 | 2.12 | 0.96 | 1.45 | 0.66 | 2.04 | 0.93 |
| 101 | Grain screenings | 89 | 2.42 | 1.10 | 1.44 | 0.65 | 0.89 | 0.40 | 1.45 | 0.66 |
| 102 | | 100 | 2.71 | 1.23 | 1.61 | 0.73 | 1.00 | 0.45 | 1.61 | 0.73 |
| 103 | Middlings | 89 | 2.33 | 1.06 | 1.38 | 0.63 | 0.83 | 0.38 | 1.40 | 0.64 |
| 104 | | 100 | 2.62 | 1.19 | 1.55 | 0.70 | 0.94 | 0.43 | 1.57 | 0.71 |
| | ***Whey*** | | | | | | | | | |
| 105 | Dehy. (Cattle) | 93 | 2.95 | 1.34 | 1.78 | 0.81 | 1.19 | 0.54 | 1.74 | 0.79 |
| 106 | | 100 | 3.16 | 1.43 | 1.91 | 0.87 | 1.27 | 0.58 | 1.87 | 0.85 |
| | ***Alfalfa*** | | | | | | | | | |
| 107 | Meal dehy., 20% | 92 | 2.12 | 0.96 | 1.25 | 0.57 | 0.66 | 0.30 | 1.28 | 0.58 |
| 108 | | 100 | 2.31 | 1.05 | 1.36 | 0.62 | 0.72 | 0.33 | 1.40 | 0.64 |
| | ***Corn, Dent Yellow*** | | | | | | | | | |
| 109 | Distillers grains, dehy. | 94 | 3.16 | 1.43 | 1.93 | 0.88 | 1.31 | 0.59 | 1.86 | 0.84 |
| 110 | | 100 | 3.38 | 1.53 | 2.06 | 0.93 | 1.40 | 0.64 | 1.99 | 0.90 |
| 111 | Distillers grains with | 92 | 3.19 | 1.45 | 1.95 | 0.88 | 1.33 | 0.60 | 1.87 | 0.85 |
| 112 | solubles, dehy. | 100 | 3.47 | 1.57 | 2.12 | 0.96 | 1.45 | 0.66 | 2.04 | 0.93 |
| 113 | Gluten, meal | 91 | 3.09 | 1.40 | 1.88 | 0.85 | 1.27 | 0.58 | 1.81 | 0.82 |
| 114 | | 100 | 3.38 | 1.53 | 2.06 | 0.93 | 1.40 | 0.64 | 1.99 | 0.90 |
| 115 | Gluten, meal, 60% | 90 | 3.17 | 1.44 | 1.95 | 0.88 | 1.33 | 0.60 | 1.86 | 0.84 |
| 116 | protein | 100 | 3.51 | 1.59 | 2.15 | 0.98 | 1.47 | 0.67 | 2.06 | 0.93 |
| 117 | Gluten with bran (Corn | 90 | 2.92 | 1.32 | 1.77 | 0.80 | 1.19 | 0.54 | 1.72 | 0.78 |
| 118 | gluten feed) | 100 | 3.25 | 1.47 | 1.97 | 0.89 | 1.32 | 0.60 | 1.91 | 0.87 |
| | ***Cotton*** | | | | | | | | | |
| 119 | Seeds, meal solv. extd. | 91 | 2.68 | 1.22 | 1.60 | 0.73 | 1.04 | 0.47 | 1.59 | 0.72 |
| 120 | 41% protein | 100 | 2.93 | 1.33 | 1.76 | 0.80 | 1.14 | 0.52 | 1.74 | 0.79 |
| | ***Fish, Anchovy*** | | | | | | | | | |
| 121 | Meal mech. extd. | 92 | 2.82 | 1.28 | 1.70 | 0.77 | 1.12 | 0.51 | 1.67 | 0.76 |
| 122 | | 100 | 3.07 | 1.39 | 1.85 | 0.84 | 1.22 | 0.55 | 1.82 | 0.83 |
| | ***Fish, Menhaden*** | | | | | | | | | |
| 123 | Meal mech. extd. | 92 | 2.57 | 1.17 | 1.53 | 0.69 | 0.97 | 0.44 | 1.53 | 0.69 |
| 124 | | 100 | 2.80 | 1.27 | 1.67 | 0.76 | 1.06 | 0.48 | 1.67 | 0.76 |

## AND THEIR ENERGY VALUES *(page 4)*

| Entry number | HORSES ME Mcal/ kg | HORSES ME Mcal/ lb | SWINE ME kcal/ kg | SWINE ME kcal/ lb | Lysine % | Crude Protein % | Calcium (Ca) % | Phosphorus (P) % | Crude Fiber % | Ash % |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Sorghum*** | | | | | | | | | | |
| 95 | - - | - - | 3,216 | 1,459 | 0.25 | 11.1 | 0.03 | 0.29 | 2.4 | 1.8 |
| 96 | - - | - - | 3,585 | 1,626 | 0.28 | 12.4 | 0.04 | 0.33 | 2.6 | 2.0 |
| ***Wheat*** | | | | | | | | | | |
| 97 | - - | - - | 2,212 | 1,003 | 0.58 | 15.2 | 0.11 | 1.22 | 10.0 | 6.1 |
| 98 | - - | - - | 2,491 | 1,130 | 0.65 | 17.1 | 0.13 | 1.38 | 11.3 | 6.9 |
| 99 | - - | - - | 3,253 | 1,476 | 0.37 | 14.2 | 0.04 | 0.37 | 2.6 | 1.7 |
| 100 | - - | - - | 3,660 | 1,660 | 0.41 | 16.0 | 0.04 | 0.42 | 2.9 | 1.9 |
| 101 | - - | - - | 2,354 | 1,068 | 0.38 | 14.1 | 0.13 | 0.35 | 6.9 | 5.5 |
| 102 | - - | - - | 2,638 | 1,197 | 0.43 | 15.8 | 0.15 | 0.39 | 7.7 | 6.1 |
| 103 | - - | - - | 2,728 | 1,237 | 0.67 | 16.4 | 0.11 | 0.88 | 7.3 | 4.7 |
| 104 | - - | - - | 3,070 | 1,393 | 0.76 | 18.4 | 0.13 | 0.99 | 8.2 | 5.2 |
| ***Whey*** | | | | | | | | | | |
| 105 | - - | - - | 3,115 | 1,413 | 0.94 | 13.3 | 0.86 | 0.76 | 0.2 | 9.2 |
| 106 | - - | - - | 3,337 | 1,514 | 1.00 | 14.2 | 0.92 | 0.82 | 0.2 | 9.8 |
| ***Alfalfa*** | | | | | | | | | | |
| 107 | 1.27 | 0.58 | 1,923 | 872 | 0.90 | 20.2 | 1.59 | 0.28 | 20.6 | 10.4 |
| 108 | 1.39 | 0.63 | 2,099 | 952 | 0.98 | 22.0 | 1.74 | 0.30 | 22.5 | 11.3 |
| ***Corn, Dent Yellow*** | | | | | | | | | | |
| 109 | - - | - - | 2,062 | 935 | 0.78 | 27.9 | 0.10 | 0.40 | 11.3 | 2.3 |
| 110 | - - | - - | 2,205 | 1,000 | 0.84 | 29.7 | 0.11 | 0.43 | 12.1 | 2.4 |
| 111 | - - | - - | 2,819 | 1,279 | 0.70 | 27.9 | 0.14 | 0.65 | 9.1 | 4.4 |
| 112 | - - | - - | 3,070 | 1,393 | 0.77 | 29.5 | 0.15 | 0.71 | 9.9 | 4.8 |
| 113 | - - | - - | 3,136 | 1,422 | 0.80 | 42.7 | 0.15 | 0.45 | 4.4 | 3.1 |
| 114 | - - | - - | 3,436 | 1,559 | 0.87 | 46.8 | 0.16 | 0.50 | 4.8 | 3.4 |
| 115 | - - | - - | 3,528 | 1,600 | 1.01 | 60.7 | 0.07 | 0.48 | 2.0 | 1.6 |
| 116 | - - | - - | 3,907 | 1,772 | 1.12 | 67.2 | 0.08 | 0.54 | 2.2 | 1.8 |
| 117 | - - | - - | 2,475 | 1,123 | 0.64 | 23.0 | 0.33 | 0.74 | 8.7 | 6.7 |
| 118 | - - | - - | 2,751 | 1,248 | 0.71 | 25.6 | 0.36 | 0.82 | 9.7 | 7.5 |
| ***Cotton*** | | | | | | | | | | |
| 119 | - - | - - | 2,364 | 1,072 | 1.69 | 41.2 | 0.17 | 1.10 | 12.1 | 6.5 |
| 120 | - - | - - | 2,592 | 1,176 | 1.86 | 45.2 | 0.18 | 1.21 | 13.3 | 7.1 |
| ***Fish, Anchovy*** | | | | | | | | | | |
| 121 | - - | - - | 2,476 | 1,123 | 5.04 | 65.5 | 3.75 | 2.49 | 1.0 | 14.8 |
| 122 | - - | - - | 2,695 | 1,222 | 5.49 | 71.2 | 4.08 | 2.70 | 1.1 | 16.1 |
| ***Fish, Menhaden*** | | | | | | | | | | |
| 123 | - - | - - | 2,633 | 1,194 | 4.72 | 61.1 | 5.18 | 2.89 | 0.9 | 19.0 |
| 124 | - - | - - | 2,875 | 1,304 | 5.15 | 66.7 | 5.65 | 3.16 | 1.0 | 20.8 |

*(continued)*

## Appendix Table 1C COMPOSITION OF SELECTED FEEDS

| Entry number | Feed Name Description | Dry Matter | RUMINANTS | | | | | | DAIRY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ME Mcal/ | | NEM Mcal/ | | NEG Mcal/ | | NEL Mcal/ | |
| | | % | kg | lb | kg | lb | kg | lb | kg | lb |
| | ***Meat*** | | | | | | | | | |
| 125 | With bone, meal | 93 | 2.53 | 1.15 | 1.50 | 0.68 | 0.93 | 0.42 | 1.51 | 0.68 |
| 126 | rendered | 100 | 2.71 | 1.23 | 1.61 | 0.73 | 1.00 | 0.45 | 1.62 | 0.73 |
| | ***Soybean*** | | | | | | | | | |
| 127 | Seeds | 92 | 3.30 | 1.50 | 2.03 | 0.92 | 1.39 | 0.63 | 1.93 | 0.88 |
| 128 | | 100 | 3.60 | 1.63 | 2.22 | 1.01 | 1.52 | 0.69 | 2.11 | 0.96 |
| 129 | Seeds, meal mech. | 90 | 3.00 | 1.36 | 1.83 | 0.83 | 1.23 | 0.56 | 1.77 | 0.80 |
| 130 | extd. | 100 | 3.34 | 1.52 | 2.03 | 0.92 | 1.37 | 0.62 | 1.96 | 0.89 |
| 131 | Seeds, meal solv. | 89 | 2.94 | 1.33 | 1.79 | 0.81 | 1.20 | 0.54 | 1.73 | 0.78 |
| 132 | extd. 44% protein | 100 | 3.29 | 1.49 | 2.00 | 0.91 | 1.35 | 0.61 | 1.94 | 0.88 |
| | ***Yeast*** | | | | | | | | | |
| 133 | Brewers, dehy. | 93 | 2.87 | 1.30 | 1.73 | 0.78 | 1.14 | 0.52 | 1.70 | 0.77 |
| 134 | | 100 | 3.07 | 1.39 | 1.85 | 0.84 | 1.22 | 0.55 | 1.82 | 0.83 |
| | ***Flax*** | | | | | | | | | |
| 135 | Seeds, meal solv. extd. | 90 | 2.73 | 1.24 | 1.64 | 0.74 | 1.08 | 0.49 | 1.62 | 0.73 |
| 136 | (Linseed meal) | 100 | 3.02 | 1.37 | 1.82 | 0.83 | 1.19 | 0.54 | 1.79 | 0.81 |

## AND THEIR ENERGY VALUES *(page 5)*

| Entry number | HORSES ME Mcal/ kg | HORSES ME Mcal/ lb | SWINE ME kcal/ kg | SWINE ME kcal/ lb | Lysine % | Crude Protein % | Calcium (Ca) % | Phosphorus (P) % | Crude Fiber % | Ash % |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Meat*** | | | | | | | | | | |
| 125 | - - | - - | 2,184 | 991 | 2.90 | 50.4 | 10.30 | 5.10 | 2.2 | 29.3 |
| 126 | - - | - - | 2,346 | 1,064 | 3.11 | 54.1 | 11.06 | 5.48 | 2.4 | 31.5 |
| ***Soybean*** | | | | | | | | | | |
| 127 | - - | - - | 3,574 | 1,621 | 2.44 | 39.2 | 0.25 | 0.60 | 5.3 | 5.1 |
| 128 | - - | - - | 3,905 | 1,771 | 2.67 | 42.8 | 0.27 | 0.65 | 5.8 | 5.5 |
| 129 | - - | - - | 2,972 | 1,348 | 2.79 | 42.9 | 0.26 | 0.61 | 5.9 | 6.0 |
| 130 | - - | - - | 3,304 | 1,499 | 3.10 | 47.7 | 0.29 | 0.68 | 6.6 | 6.7 |
| 131 | - - | - - | 1,278 | 580 | 2.68 | 44.6 | 0.30 | 0.63 | 6.2 | 6.5 |
| 132 | - - | - - | 1,431 | 649 | 2.99 | 49.9 | 0.34 | 0.70 | 7.0 | 7.3 |
| ***Yeast*** | | | | | | | | | | |
| 133 | - - | - - | 2,876 | 1,305 | 3.11 | 43.8 | 0.12 | 1.40 | 2.9 | 6.6 |
| 134 | - - | - - | 3,078 | 1,396 | 3.33 | 46.9 | 0.13 | 1.49 | 3.1 | 7.1 |
| ***Flax*** | | | | | | | | | | |
| 135 | - - | - - | 2,523 | 1,144 | 1.16 | 34.6 | 0.39 | 0.80 | 9.1 | 5.8 |
| 136 | - - | - - | 2,797 | 1,269 | 1.28 | 38.3 | 0.43 | 0.89 | 10.1 | 6.5 |

**Appendix Table 1C Composition of Selected Feeds and Their Energy Values** was compiled from National Research Council, *United States–Canadian Tables of Feed Composition,* third revision, Subcommittee on Feed Composition, Committee on Animal Nutrition, Board on Agriculture and Renewable Resources, Commission on Natural Resources (Washington, DC), 1982.

**Appendix Table 1 NR** Nutrient Requirements for Growing and Finishing Cattle
(Nutrient concentration in diet dry matter, avoirdupois system)

| Weight (lb) | Daily Gain (lb) | Dry Matter Intake (lb) | Protein (%) | NEM (Mcal/lb) | NEG (Mcal/lb) | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|
| | | | ***Medium-frame steer calves*** | | | | |
| 300 | 0.5 | 7.8 | 9.6 | 0.50 | 0.25 | 0.31 | 0.20 |
| | 1.0 | 8.4 | 11.4 | 0.57 | 0.31 | 0.45 | 0.24 |
| | 1.5 | 8.7 | 13.2 | 0.64 | 0.38 | 0.58 | 0.28 |
| | 2.0 | 8.9 | 14.8 | 0.70 | 0.44 | 0.72 | 0.32 |
| | 2.5 | 8.9 | 16.7 | 0.79 | 0.51 | 0.87 | 0.37 |
| | 3.0 | 8.0 | 19.9 | 0.95 | 0.64 | 1.13 | 0.47 |
| 400 | 0.5 | 9.7 | 8.9 | 0.50 | 0.25 | 0.27 | 0.18 |
| | 1.0 | 10.4 | 10.3 | 0.57 | 0.31 | 0.38 | 0.21 |
| | 1.5 | 10.8 | 11.5 | 0.64 | 0.38 | 0.47 | 0.25 |
| | 2.0 | 11.0 | 12.7 | 0.70 | 0.44 | 0.56 | 0.26 |
| | 2.5 | 11.0 | 14.2 | 0.79 | 0.51 | 0.68 | 0.30 |
| | 3.0 | 10.0 | 16.6 | 0.95 | 0.64 | 0.86 | 0.37 |
| 500 | 0.5 | 11.5 | 8.5 | 0.50 | 0.25 | 0.25 | 0.17 |
| | 1.0 | 12.3 | 9.5 | 0.57 | 0.31 | 0.32 | 0.20 |
| | 1.5 | 12.8 | 10.5 | 0.64 | 0.38 | 0.40 | 0.22 |
| | 2.0 | 13.1 | 11.4 | 0.70 | 0.44 | 0.47 | 0.24 |
| | 2.5 | 13.0 | 12.5 | 0.79 | 0.51 | 0.56 | 0.27 |
| | 3.0 | 11.8 | 14.4 | 0.95 | 0.64 | 0.69 | 0.32 |
| 600 | 0.5 | 13.2 | 8.2 | 0.50 | 0.25 | 0.23 | 0.18 |
| | 1.0 | 14.1 | 9.0 | 0.57 | 0.31 | 0.28 | 0.19 |
| | 1.5 | 14.7 | 9.8 | 0.64 | 0.38 | 0.35 | 0.21 |
| | 2.0 | 15.0 | 10.5 | 0.70 | 0.44 | 0.40 | 0.22 |
| | 2.5 | 14.9 | 11.4 | 0.79 | 0.51 | 0.46 | 0.24 |
| | 3.0 | 13.5 | 12.9 | 0.95 | 0.64 | 0.57 | 0.29 |
| 700 | 0.5 | 14.8 | 7.9 | 0.50 | 0.25 | 0.22 | 0.18 |
| | 1.0 | 15.8 | 8.6 | 0.57 | 0.31 | 0.27 | 0.18 |
| | 1.5 | 16.5 | 9.2 | 0.64 | 0.38 | 0.31 | 0.20 |
| | 2.0 | 16.8 | 9.8 | 0.70 | 0.44 | 0.34 | 0.21 |
| | 2.5 | 16.7 | 10.5 | 0.79 | 0.51 | 0.40 | 0.22 |
| | 3.0 | 15.2 | 11.7 | 0.95 | 0.64 | 0.49 | 0.26 |
| 800 | 0.5 | 16.4 | 7.7 | 0.50 | 0.25 | 0.22 | 0.17 |
| | 1.0 | 17.5 | 8.3 | 0.57 | 0.31 | 0.24 | 0.19 |
| | 1.5 | 18.2 | 8.8 | 0.64 | 0.38 | 0.28 | 0.19 |
| | 2.0 | 18.6 | 9.2 | 0.70 | 0.44 | 0.31 | 0.20 |
| | 2.5 | 18.5 | 9.8 | 0.79 | 0.51 | 0.35 | 0.21 |
| | 3.0 | 16.8 | 10.8 | 0.95 | 0.64 | 0.42 | 0.25 |
| 900 | 0.5 | 17.9 | 7.6 | 0.50 | 0.25 | 0.21 | 0.18 |
| | 1.0 | 19.1 | 8.0 | 0.57 | 0.31 | 0.23 | 0.18 |
| | 1.5 | 19.9 | 8.4 | 0.64 | 0.38 | 0.25 | 0.19 |
| | 2.0 | 20.3 | 8.8 | 0.70 | 0.44 | 0.28 | 0.20 |
| | 2.5 | 20.2 | 9.3 | 0.79 | 0.51 | 0.31 | 0.20 |
| | 3.0 | 18.3 | 10.1 | 0.95 | 0.64 | 0.37 | 0.23 |
| 1000 | 0.5 | 19.3 | 7.5 | 0.50 | 0.25 | 0.21 | 0.18 |
| | 1.0 | 20.7 | 7.8 | 0.57 | 0.31 | 0.21 | 0.18 |
| | 1.5 | 21.5 | 8.1 | 0.64 | 0.38 | 0.24 | 0.18 |
| | 2.0 | 22.0 | 8.4 | 0.70 | 0.44 | 0.25 | 0.19 |
| | 2.5 | 21.9 | 8.8 | 0.79 | 0.51 | 0.27 | 0.19 |
| | 3.0 | 19.8 | 9.5 | 0.95 | 0.64 | 0.32 | 0.22 |

*(continued)*

**Appendix Table 1 NR** *(page 2)*

| Weight (lb) | Daily Gain (lb) | Dry Matter Intake (lb) | Protein (%) | NEM (Mcal/lb) | NEG (Mcal/lb) | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|
| ***Large-frame steer calves and compensating medium-frame yearling steers*** | | | | | | | |
| 300 | 0.5 | 8.2 | 9.5 | 0.48 | 0.23 | 0.30 | 0.19 |
| | 1.0 | 8.7 | 11.3 | 0.54 | 0.28 | 0.46 | 0.23 |
| | 1.5 | 9.1 | 12.9 | 0.59 | 0.33 | 0.58 | 0.27 |
| | 2.0 | 9.4 | 14.6 | 0.64 | 0.38 | 0.70 | 0.30 |
| | 2.5 | 9.6 | 16.3 | 0.70 | 0.44 | 0.85 | 0.34 |
| | 3.0 | 9.6 | 18.0 | 0.77 | 0.49 | 0.99 | 0.39 |
| | 3.5 | 9.3 | 20.3 | 0.86 | 0.57 | 1.16 | 0.45 |
| 400 | 0.5 | 10.1 | 8.9 | 0.48 | 0.23 | 0.26 | 0.17 |
| | 1.0 | 10.8 | 10.2 | 0.54 | 0.28 | 0.37 | 0.20 |
| | 1.5 | 11.3 | 11.4 | 0.59 | 0.33 | 0.47 | 0.23 |
| | 2.0 | 11.7 | 12.7 | 0.64 | 0.38 | 0.57 | 0.26 |
| | 2.5 | 11.9 | 13.9 | 0.70 | 0.44 | 0.65 | 0.30 |
| | 3.0 | 11.9 | 15.2 | 0.77 | 0.49 | 0.76 | 0.33 |
| | 3.5 | 11.5 | 16.9 | 0.86 | 0.57 | 0.90 | 0.36 |
| 500 | 0.5 | 12.0 | 8.5 | 0.48 | 0.23 | 0.24 | 0.17 |
| | 1.0 | 12.8 | 9.5 | 0.54 | 0.28 | 0.33 | 0.19 |
| | 1.5 | 13.4 | 10.4 | 0.59 | 0.33 | 0.39 | 0.21 |
| | 2.0 | 13.8 | 11.4 | 0.64 | 0.38 | 0.46 | 0.24 |
| | 2.5 | 14.0 | 12.4 | 0.70 | 0.44 | 0.55 | 0.25 |
| | 3.0 | 14.0 | 13.4 | 0.77 | 0.49 | 0.63 | 0.28 |
| | 3.5 | 13.6 | 14.7 | 0.86 | 0.57 | 0.73 | 0.32 |
| 600 | 0.5 | 13.8 | 8.2 | 0.48 | 0.23 | 0.22 | 0.18 |
| | 1.0 | 14.6 | 9.0 | 0.54 | 0.28 | 0.29 | 0.18 |
| | 1.5 | 15.3 | 9.7 | 0.59 | 0.33 | 0.35 | 0.20 |
| | 2.0 | 15.8 | 10.5 | 0.64 | 0.38 | 0.40 | 0.22 |
| | 2.5 | 16.1 | 11.3 | 0.70 | 0.44 | 0.47 | 0.23 |
| | 3.0 | 16.1 | 12.1 | 0.77 | 0.49 | 0.52 | 0.26 |
| | 3.5 | 15.6 | 13.2 | 0.86 | 0.57 | 0.61 | 0.28 |
| 700 | 0.5 | 15.4 | 7.9 | 0.48 | 0.23 | 0.21 | 0.17 |
| | 1.0 | 16.4 | 8.6 | 0.54 | 0.28 | 0.27 | 0.19 |
| | 1.5 | 17.2 | 9.2 | 0.59 | 0.33 | 0.31 | 0.19 |
| | 2.0 | 17.8 | 9.8 | 0.64 | 0.38 | 0.36 | 0.21 |
| | 2.5 | 18.0 | 10.5 | 0.70 | 0.44 | 0.40 | 0.22 |
| | 3.0 | 18.0 | 11.1 | 0.77 | 0.49 | 0.45 | 0.23 |
| | 3.5 | 17.5 | 12.0 | 0.86 | 0.57 | 0.52 | 0.26 |
| 800 | 0.5 | 17.1 | 7.7 | 0.48 | 0.23 | 0.21 | 0.18 |
| | 1.0 | 18.2 | 8.3 | 0.54 | 0.28 | 0.24 | 0.18 |
| | 1.5 | 19.0 | 8.8 | 0.59 | 0.33 | 0.28 | 0.19 |
| | 2.0 | 19.6 | 9.3 | 0.64 | 0.38 | 0.32 | 0.20 |
| | 2.5 | 19.9 | 9.8 | 0.70 | 0.44 | 0.35 | 0.21 |
| | 3.0 | 19.9 | 10.4 | 0.77 | 0.49 | 0.40 | 0.22 |
| | 3.5 | 19.3 | 11.1 | 0.86 | 0.57 | 0.45 | 0.24 |
| 900 | 0.5 | 18.6 | 7.6 | 0.48 | 0.23 | 0.20 | 0.18 |
| | 1.0 | 19.8 | 8.0 | 0.54 | 0.28 | 0.23 | 0.18 |
| | 1.5 | 20.8 | 8.5 | 0.59 | 0.33 | 0.27 | 0.18 |
| | 2.0 | 21.4 | 8.9 | 0.64 | 0.38 | 0.29 | 0.20 |
| | 2.5 | 21.8 | 9.3 | 0.70 | 0.44 | 0.31 | 0.20 |
| | 3.0 | 21.7 | 9.8 | 0.77 | 0.49 | 0.36 | 0.21 |
| | 3.5 | 21.1 | 10.4 | 0.86 | 0.57 | 0.40 | 0.23 |
| 1000 | 0.5 | 20.2 | 7.5 | 0.48 | 0.23 | 0.20 | 0.17 |
| | 1.0 | 21.5 | 7.8 | 0.54 | 0.28 | 0.23 | 0.17 |
| | 1.5 | 22.5 | 8.2 | 0.59 | 0.33 | 0.25 | 0.18 |
| | 2.0 | 23.2 | 8.6 | 0.64 | 0.38 | 0.27 | 0.18 |
| | 2.5 | 23.6 | 8.9 | 0.70 | 0.44 | 0.29 | 0.19 |
| | 3.0 | 23.6 | 9.3 | 0.77 | 0.49 | 0.32 | 0.20 |
| | 3.5 | 22.8 | 9.8 | 0.86 | 0.57 | 0.35 | 0.21 |
| 1100 | 0.5 | 21.7 | 7.4 | 0.48 | 0.23 | 0.19 | 0.18 |
| | 1.0 | 23.1 | 7.7 | 0.54 | 0.28 | 0.21 | 0.18 |
| | 1.5 | 24.1 | 8.0 | 0.59 | 0.33 | 0.23 | 0.18 |
| | 2.0 | 24.9 | 8.3 | 0.64 | 0.38 | 0.25 | 0.18 |
| | 2.5 | 25.3 | 8.5 | 0.70 | 0.44 | 0.26 | 0.18 |
| | 3.0 | 25.3 | 8.9 | 0.77 | 0.49 | 0.29 | 0.19 |
| | 3.5 | 24.5 | 9.3 | 0.86 | 0.57 | 0.32 | 0.21 |

*(continued)*

**Appendix Table 1 NR** *(page 3)*

| Weight (lb) | Daily Gain (lb) | Dry Matter Intake (lb) | Protein (%) | NEM (Mcal/lb) | NEG (Mcal/lb) | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|
| | | | ***Medium-frame bulls*** | | | | |
| 300 | 0.5 | 7.8 | 9.7 | 0.49 | 0.24 | 0.31 | 0.20 |
| | 1.0 | 8.3 | 11.6 | 0.56 | 0.30 | 0.48 | 0.24 |
| | 1.5 | 8.6 | 13.4 | 0.62 | 0.35 | 0.62 | 0.28 |
| | 2.0 | 8.8 | 15.2 | 0.68 | 0.41 | 0.75 | 0.33 |
| | 2.5 | 8.9 | 17.0 | 0.74 | 0.47 | 0.92 | 0.37 |
| | 3.0 | 8.7 | 19.3 | 0.84 | 0.54 | 1.09 | 0.43 |
| 400 | 0.5 | 9.6 | 9.0 | 0.49 | 0.24 | 0.28 | 0.18 |
| | 1.0 | 10.3 | 10.4 | 0.56 | 0.30 | 0.39 | 0.21 |
| | 1.5 | 10.7 | 11.8 | 0.62 | 0.35 | 0.49 | 0.25 |
| | 2.0 | 11.0 | 13.1 | 0.68 | 0.41 | 0.60 | 0.28 |
| | 2.5 | 11.1 | 14.4 | 0.74 | 0.47 | 0.70 | 0.32 |
| | 3.0 | 10.8 | 16.1 | 0.84 | 0.54 | 0.84 | 0.37 |
| 500 | 0.5 | 11.4 | 8.6 | 0.49 | 0.24 | 0.25 | 0.17 |
| | 1.0 | 12.1 | 9.7 | 0.56 | 0.30 | 0.35 | 0.20 |
| | 1.5 | 12.7 | 10.7 | 0.62 | 0.35 | 0.42 | 0.23 |
| | 2.0 | 13.0 | 11.7 | 0.68 | 0.41 | 0.49 | 0.25 |
| | 2.5 | 13.1 | 12.8 | 0.74 | 0.47 | 0.59 | 0.27 |
| | 3.0 | 12.8 | 14.1 | 0.84 | 0.54 | 0.69 | 0.31 |
| 600 | 0.5 | 13.1 | 8.3 | 0.49 | 0.24 | 0.24 | 0.19 |
| | 1.0 | 13.9 | 9.2 | 0.56 | 0.30 | 0.30 | 0.19 |
| | 1.5 | 14.5 | 10.0 | 0.62 | 0.35 | 0.36 | 0.21 |
| | 2.0 | 14.9 | 10.8 | 0.68 | 0.41 | 0.43 | 0.24 |
| | 2.5 | 15.0 | 11.6 | 0.74 | 0.47 | 0.50 | 0.25 |
| | 3.0 | 14.7 | 12.7 | 0.84 | 0.54 | 0.57 | 0.29 |
| 700 | 0.5 | 14.7 | 8.0 | 0.49 | 0.24 | 0.23 | 0.18 |
| | 1.0 | 15.6 | 8.8 | 0.56 | 0.30 | 0.28 | 0.20 |
| | 1.5 | 16.3 | 9.4 | 0.62 | 0.35 | 0.32 | 0.20 |
| | 2.0 | 16.7 | 10.1 | 0.68 | 0.41 | 0.38 | 0.22 |
| | 2.5 | 16.8 | 10.8 | 0.74 | 0.47 | 0.43 | 0.24 |
| | 3.0 | 16.5 | 11.7 | 0.84 | 0.54 | 0.49 | 0.25 |
| 800 | 0.5 | 16.2 | 7.8 | 0.49 | 0.24 | 0.22 | 0.19 |
| | 1.0 | 17.3 | 8.4 | 0.56 | 0.30 | 0.25 | 0.19 |
| | 1.5 | 18.0 | 9.0 | 0.62 | 0.35 | 0.29 | 0.20 |
| | 2.0 | 18.5 | 9.5 | 0.68 | 0.41 | 0.33 | 0.21 |
| | 2.5 | 18.6 | 10.1 | 0.74 | 0.47 | 0.38 | 0.23 |
| | 3.0 | 18.2 | 10.8 | 0.84 | 0.54 | 0.44 | 0.24 |
| 900 | 0.5 | 17.7 | 7.7 | 0.49 | 0.24 | 0.21 | 0.19 |
| | 1.0 | 18.9 | 8.2 | 0.56 | 0.30 | 0.25 | 0.19 |
| | 1.5 | 19.7 | 8.6 | 0.62 | 0.35 | 0.28 | 0.19 |
| | 2.0 | 20.2 | 9.1 | 0.68 | 0.41 | 0.31 | 0.21 |
| | 2.5 | 20.3 | 9.6 | 0.74 | 0.47 | 0.34 | 0.22 |
| | 3.0 | 19.9 | 10.2 | 0.84 | 0.54 | 0.39 | 0.23 |
| 1000 | 0.5 | 19.2 | 7.5 | 0.49 | 0.24 | 0.21 | 0.18 |
| | 1.0 | 20.4 | 8.0 | 0.56 | 0.30 | 0.24 | 0.18 |
| | 1.5 | 21.3 | 8.4 | 0.62 | 0.35 | 0.26 | 0.19 |
| | 2.0 | 21.8 | 8.7 | 0.68 | 0.41 | 0.28 | 0.19 |
| | 2.5 | 22.0 | 9.1 | 0.74 | 0.47 | 0.31 | 0.20 |
| | 3.0 | 21.5 | 9.6 | 0.84 | 0.54 | 0.35 | 0.22 |
| 1100 | 0.5 | 20.6 | 7.4 | 0.49 | 0.24 | 0.20 | 0.19 |
| | 1.0 | 21.9 | 7.8 | 0.56 | 0.30 | 0.22 | 0.19 |
| | 1.5 | 22.9 | 8.1 | 0.62 | 0.35 | 0.24 | 0.19 |
| | 2.0 | 23.4 | 8.4 | 0.68 | 0.41 | 0.26 | 0.19 |
| | 2.5 | 23.6 | 8.7 | 0.74 | 0.47 | 0.28 | 0.20 |
| | 3.0 | 23.1 | 9.2 | 0.84 | 0.54 | 0.32 | 0.21 |

*(continued)*

**Appendix Table 1 NR** *(page 4)*

| Weight (lb) | Daily Gain (lb) | Dry Matter Intake (lb) | Protein (%) | NEM (Mcal/lb) | NEG (Mcal/lb) | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|
| ***Large-frame bull calves and compensating large-frame yearling steers*** | | | | | | | |
| 300 | 0.5 | 7.9 | 9.7 | 0.48 | 0.23 | 0.31 | 0.20 |
| | 1.0 | 8.4 | 11.7 | 0.54 | 0.28 | 0.47 | 0.24 |
| | 1.5 | 8.8 | 13.5 | 0.59 | 0.33 | 0.63 | 0.28 |
| | 2.0 | 9.0 | 15.1 | 0.63 | 0.37 | 0.76 | 0.32 |
| | 2.5 | 9.2 | 17.0 | 0.69 | 0.42 | 0.91 | 0.36 |
| | 3.0 | 9.2 | 18.8 | 0.75 | 0.47 | 1.08 | 0.43 |
| | 3.5 | 9.1 | 20.9 | 0.82 | 0.53 | 1.24 | 0.48 |
| | 4.0 | 8.2 | 24.7 | 0.96 | 0.66 | 1.53 | 0.59 |
| 400 | 0.5 | 9.8 | 9.0 | 0.48 | 0.23 | 0.27 | 0.18 |
| | 1.0 | 10.4 | 10.5 | 0.54 | 0.28 | 0.40 | 0.21 |
| | 1.5 | 10.9 | 11.9 | 0.59 | 0.33 | 0.51 | 0.24 |
| | 2.0 | 11.2 | 13.1 | 0.63 | 0.37 | 0.61 | 0.28 |
| | 2.5 | 11.4 | 14.5 | 0.69 | 0.42 | 0.72 | 0.31 |
| | 3.0 | 11.5 | 15.9 | 0.75 | 0.47 | 0.82 | 0.35 |
| | 3.5 | 11.3 | 17.5 | 0.82 | 0.53 | 0.96 | 0.39 |
| | 4.0 | 10.2 | 20.3 | 0.96 | 0.66 | 1.19 | 0.48 |
| 500 | 0.5 | 11.6 | 8.6 | 0.48 | 0.23 | 0.25 | 0.19 |
| | 1.0 | 12.3 | 9.8 | 0.54 | 0.28 | 0.36 | 0.21 |
| | 1.5 | 12.9 | 10.9 | 0.59 | 0.33 | 0.43 | 0.22 |
| | 2.0 | 13.2 | 11.8 | 0.63 | 0.37 | 0.52 | 0.25 |
| | 2.5 | 13.5 | 12.9 | 0.69 | 0.42 | 0.59 | 0.28 |
| | 3.0 | 13.6 | 14.0 | 0.75 | 0.47 | 0.68 | 0.31 |
| | 3.5 | 13.4 | 15.3 | 0.82 | 0.53 | 0.77 | 0.35 |
| | 4.0 | 12.0 | 17.5 | 0.96 | 0.66 | 0.97 | 0.40 |
| 600 | 0.5 | 13.3 | 8.3 | 0.48 | 0.23 | 0.23 | 0.18 |
| | 1.0 | 14.1 | 9.2 | 0.54 | 0.28 | 0.31 | 0.20 |
| | 1.5 | 14.8 | 10.1 | 0.59 | 0.33 | 0.37 | 0.21 |
| | 2.0 | 15.2 | 10.9 | 0.63 | 0.37 | 0.44 | 0.23 |
| | 2.5 | 15.5 | 11.8 | 0.69 | 0.42 | 0.51 | 0.26 |
| | 3.0 | 15.5 | 12.7 | 0.75 | 0.47 | 0.58 | 0.27 |
| | 3.5 | 15.3 | 13.7 | 0.82 | 0.53 | 0.66 | 0.30 |
| | 4.0 | 13.8 | 15.6 | 0.96 | 0.66 | 0.81 | 0.37 |
| 700 | 0.5 | 14.9 | 8.0 | 0.48 | 0.23 | 0.22 | 0.18 |
| | 1.0 | 15.9 | 8.8 | 0.54 | 0.26 | 0.29 | 0.19 |
| | 1.5 | 16.6 | 9.6 | 0.59 | 0.33 | 0.35 | 0.21 |
| | 2.0 | 17.0 | 10.2 | 0.63 | 0.37 | 0.39 | 0.22 |
| | 2.5 | 17.4 | 11.0 | 0.69 | 0.42 | 0.44 | 0.24 |
| | 3.0 | 17.5 | 11.7 | 0.75 | 0.47 | 0.50 | 0.25 |
| | 3.5 | 17.2 | 12.5 | 0.82 | 0.53 | 0.56 | 0.28 |
| | 4.0 | 15.5 | 14.1 | 0.96 | 0.66 | 0.70 | 0.33 |
| 800 | 0.5 | 16.5 | 7.9 | 0.48 | 0.23 | 0.21 | 0.19 |
| | 1.0 | 17.5 | 8.5 | 0.54 | 0.28 | 0.26 | 0.19 |
| | 1.5 | 18.3 | 9.1 | 0.59 | 0.33 | 0.31 | 0.20 |
| | 2.0 | 18.8 | 9.7 | 0.63 | 0.37 | 0.35 | 0.21 |
| | 2.5 | 19.2 | 10.3 | 0.69 | 0.42 | 0.40 | 0.23 |
| | 3.0 | 19.3 | 10.9 | 0.75 | 0.47 | 0.45 | 0.24 |
| | 3.5 | 19.0 | 11.6 | 0.82 | 0.53 | 0.50 | 0.26 |
| | 4.0 | 17.1 | 13.0 | 0.96 | 0.66 | 0.61 | 0.31 |
| 900 | 0.5 | 18.0 | 7.7 | 0.48 | 0.23 | 0.22 | 0.18 |
| | 1.0 | 19.2 | 8.3 | 0.54 | 0.28 | 0.25 | 0.18 |
| | 1.5 | 20.0 | 8.8 | 0.59 | 0.33 | 0.29 | 0.20 |
| | 2.0 | 20.6 | 9.2 | 0.63 | 0.37 | 0.32 | 0.20 |
| | 2.5 | 21.0 | 9.8 | 0.69 | 0.42 | 0.36 | 0.21 |
| | 3.0 | 21.1 | 10.3 | 0.75 | 0.47 | 0.40 | 0.23 |
| | 3.5 | 20.8 | 10.9 | 0.82 | 0.53 | 0.45 | 0.24 |
| | 4.0 | 18.7 | 12.1 | 0.96 | 0.66 | 0.53 | 0.28 |

*(continued)*

**Appendix Table 1 NR** *(page 5)*

| Weight (lb) | Daily Gain (lb) | Dry Matter Intake (lb) | Protein (%) | NEM (Mcal/lb) | NEG (Mcal/lb) | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|
| ***Large-frame bull calves and compensating large-frame yearling steers*** *(continued)* | | | | | | | |
| 1000 | 0.5 | 19.5 | 7.6 | 0.48 | 0.23 | 0.21 | 0.18 |
| | 1.0 | 20.7 | 8.1 | 0.54 | 0.28 | 0.25 | 0.19 |
| | 1.5 | 21.7 | 8.5 | 0.59 | 0.33 | 0.27 | 0.19 |
| | 2.0 | 22.3 | 8.9 | 0.63 | 0.37 | 0.30 | 0.20 |
| | 2.5 | 22.7 | 9.3 | 0.69 | 0.42 | 0.33 | 0.20 |
| | 3.0 | 22.8 | 9.7 | 0.75 | 0.47 | 0.36 | 0.21 |
| | 3.5 | 22.5 | 10.3 | 0.82 | 0.53 | 0.40 | 0.24 |
| | 4.0 | 20.2 | 11.3 | 0.96 | 0.66 | 0.48 | 0.27 |
| 1100 | 0.5 | 20.9 | 7.5 | 0.48 | 0.23 | 0.21 | 0.19 |
| | 1.0 | 22.3 | 7.9 | 0.54 | 0.28 | 0.23 | 0.19 |
| | 1.5 | 23.3 | 8.3 | 0.59 | 0.33 | 0.26 | 0.19 |
| | 2.0 | 23.9 | 8.6 | 0.63 | 0.37 | 0.28 | 0.19 |
| | 2.5 | 24.2 | 9.0 | 0.69 | 0.42 | 0.30 | 0.20 |
| | 3.0 | 24.5 | 9.3 | 0.75 | 0.47 | 0.32 | 0.21 |
| | 3.5 | 24.1 | 9.8 | 0.82 | 0.53 | 0.36 | 0.22 |
| | 4.0 | 21.7 | 10.7 | 0.96 | 0.66 | 0.43 | 0.25 |
| ***Medium-frame heifer calves*** | | | | | | | |
| 300 | 0.5 | 7.5 | 9.6 | 0.54 | 0.28 | 0.29 | 0.21 |
| | 1.0 | 8.0 | 11.4 | 0.63 | 0.36 | 0.44 | 0.22 |
| | 1.5 | 8.2 | 13.1 | 0.72 | 0.44 | 0.59 | 0.27 |
| | 2.0 | 8.0 | 15.1 | 0.84 | 0.55 | 0.74 | 0.33 |
| 400 | 0.5 | 9.3 | 8.9 | 0.54 | 0.28 | 0.26 | 0.19 |
| | 1.0 | 9.9 | 10.2 | 0.63 | 0.36 | 0.36 | 0.20 |
| | 1.5 | 10.2 | 11.4 | 0.72 | 0.44 | 0.45 | 0.24 |
| | 2.0 | 10.0 | 12.9 | 0.84 | 0.55 | 0.57 | 0.29 |
| 500 | 0.5 | 11.0 | 8.5 | 0.54 | 0.28 | 0.24 | 0.18 |
| | 1.0 | 11.8 | 9.4 | 0.63 | 0.36 | 0.30 | 0.21 |
| | 1.5 | 12.1 | 10.3 | 0.72 | 0.44 | 0.38 | 0.22 |
| | 2.0 | 11.8 | 11.4 | 0.84 | 0.55 | 0.45 | 0.24 |
| 600 | 0.5 | 12.6 | 8.1 | 0.54 | 0.28 | 0.23 | 0.18 |
| | 1.0 | 13.5 | 8.8 | 0.63 | 0.36 | 0.28 | 0.20 |
| | 1.5 | 13.8 | 9.5 | 0.72 | 0.44 | 0.32 | 0.21 |
| | 2.0 | 13.5 | 10.4 | 0.84 | 0.55 | 0.38 | 0.23 |
| 700 | 0.5 | 14.1 | 7.9 | 0.54 | 0.28 | 0.22 | 0.19 |
| | 1.0 | 15.1 | 8.4 | 0.63 | 0.36 | 0.25 | 0.19 |
| | 1.5 | 15.5 | 9.0 | 0.72 | 0.44 | 0.28 | 0.20 |
| | 2.0 | 15.2 | 9.6 | 0.84 | 0.55 | 0.32 | 0.22 |
| 800 | 0.5 | 15.6 | 7.7 | 0.54 | 0.28 | 0.21 | 0.18 |
| | 1.0 | 16.7 | 8.1 | 0.63 | 0.36 | 0.22 | 0.18 |
| | 1.5 | 17.2 | 8.5 | 0.72 | 0.44 | 0.24 | 0.19 |
| | 2.0 | 16.8 | 9.0 | 0.84 | 0.55 | 0.28 | 0.20 |
| 900 | 0.5 | 17.1 | 7.5 | 0.54 | 0.28 | 0.21 | 0.18 |
| | 1.0 | 18.3 | 7.8 | 0.63 | 0.36 | 0.22 | 0.18 |
| | 1.5 | 18.8 | 8.1 | 0.72 | 0.44 | 0.22 | 0.19 |
| | 2.0 | 18.3 | 8.5 | 0.84 | 0.55 | 0.25 | 0.19 |
| 1000 | 0.5 | 18.5 | 7.4 | 0.54 | 0.28 | 0.20 | 0.19 |
| | 1.0 | 19.8 | 7.6 | 0.63 | 0.36 | 0.20 | 0.18 |
| | 1.5 | 20.3 | 7.8 | 0.72 | 0.44 | 0.21 | 0.18 |
| | 2.0 | 19.8 | 8.1 | 0.84 | 0.55 | 0.22 | 0.19 |

*(continued)*

**Appendix Table 1 NR** *(page 6)*

| Weight (lb) | Daily Gain (lb) | Dry Matter Intake (lb) | Protein (%) | NEM (Mcal/lb) | NEG (Mcal/lb) | Ca (%) | P (%) |
|---|---|---|---|---|---|---|---|
| ***Large-frame heifer calves and compensating medium-frame yearling heifers*** | | | | | | | |
| 300 | 0.5 | 7.8 | 9.5 | 0.50 | 0.25 | 0.31 | 0.20 |
| | 1.0 | 8.4 | 11.3 | 0.58 | 0.32 | 0.45 | 0.24 |
| | 1.5 | 8.8 | 13.0 | 0.65 | 0.39 | 0.58 | 0.25 |
| | 2.0 | 8.9 | 14.6 | 0.74 | 0.46 | 0.69 | 0.30 |
| | 2.5 | 8.7 | 16.7 | 0.84 | 0.55 | 0.86 | 0.35 |
| 400 | 0.5 | 9.7 | 8.9 | 0.50 | 0.25 | 0.27 | 0.18 |
| | 1.0 | 10.5 | 10.1 | 0.58 | 0.32 | 0.36 | 0.21 |
| | 1.5 | 10.9 | 11.3 | 0.65 | 0.39 | 0.45 | 0.22 |
| | 2.0 | 11.1 | 12.6 | 0.74 | 0.46 | 0.54 | 0.26 |
| | 2.5 | 10.8 | 14.1 | 0.84 | 0.55 | 0.65 | 0.31 |
| 500 | 0.5 | 11.5 | 8.4 | 0.50 | 0.25 | 0.23 | 0.17 |
| | 1.0 | 12.4 | 9.4 | 0.58 | 0.32 | 0.30 | 0.20 |
| | 1.5 | 12.9 | 10.3 | 0.65 | 0.39 | 0.38 | 0.20 |
| | 2.0 | 13.1 | 11.2 | 0.74 | 0.46 | 0.44 | 0.24 |
| | 2.5 | 12.8 | 12.4 | 0.84 | 0.55 | 0.53 | 0.26 |
| 600 | 0.5 | 13.2 | 8.1 | 0.50 | 0.25 | 0.22 | 0.18 |
| | 1.0 | 14.1 | 8.9 | 0.58 | 0.32 | 0.28 | 0.19 |
| | 1.5 | 14.8 | 9.6 | 0.65 | 0.39 | 0.33 | 0.19 |
| | 2.0 | 15.0 | 10.3 | 0.74 | 0.46 | 0.38 | 0.22 |
| | 2.5 | 14.6 | 11.2 | 0.84 | 0.55 | 0.44 | 0.24 |
| 700 | 0.5 | 14.8 | 7.9 | 0.50 | 0.25 | 0.21 | 0.18 |
| | 1.0 | 15.9 | 8.5 | 0.58 | 0.32 | 0.25 | 0.18 |
| | 1.5 | 16.6 | 9.0 | 0.65 | 0.39 | 0.29 | 0.19 |
| | 2.0 | 16.8 | 9.6 | 0.74 | 0.46 | 0.33 | 0.20 |
| | 2.5 | 16.4 | 10.3 | 0.84 | 0.55 | 0.38 | 0.22 |
| 800 | 0.5 | 16.4 | 7.7 | 0.50 | 0.25 | 0.20 | 0.17 |
| | 1.0 | 17.6 | 8.2 | 0.58 | 0.32 | 0.24 | 0.18 |
| | 1.5 | 18.3 | 8.6 | 0.65 | 0.39 | 0.25 | 0.18 |
| | 2.0 | 18.6 | 9.0 | 0.74 | 0.46 | 0.28 | 0.19 |
| | 2.5 | 18.1 | 9.6 | 0.84 | 0.55 | 0.33 | 0.21 |
| 900 | 0.5 | 17.8 | 7.5 | 0.50 | 0.25 | 0.20 | 0.18 |
| | 1.0 | 19.2 | 7.9 | 0.58 | 0.32 | 0.22 | 0.18 |
| | 1.5 | 20.0 | 8.2 | 0.65 | 0.39 | 0.23 | 0.18 |
| | 2.0 | 20.3 | 8.6 | 0.74 | 0.46 | 0.26 | 0.18 |
| | 2.5 | 19.8 | 9.0 | 0.84 | 0.55 | 0.29 | 0.20 |
| 1000 | 0.5 | 19.3 | 7.4 | 0.50 | 0.25 | 0.19 | 0.18 |
| | 1.0 | 20.8 | 7.7 | 0.58 | 0.32 | 0.21 | 0.18 |
| | 1.5 | 21.7 | 8.0 | 0.65 | 0.39 | 0.21 | 0.18 |
| | 2.0 | 22.0 | 8.2 | 0.74 | 0.46 | 0.23 | 0.18 |
| | 2.5 | 21.5 | 8.6 | 0.84 | 0.55 | 0.25 | 0.18 |
| 1100 | 0.5 | 20.8 | 7.3 | 0.50 | 0.25 | 0.19 | 0.18 |
| | 1.0 | 22.3 | 7.5 | 0.58 | 0.32 | 0.20 | 0.18 |
| | 1.5 | 23.3 | 7.7 | 0.65 | 0.39 | 0.20 | 0.18 |
| | 2.0 | 23.6 | 7.9 | 0.74 | 0.46 | 0.21 | 0.18 |
| | 2.5 | 23.1 | 8.2 | 0.84 | 0.55 | 0.22 | 0.18 |

[a] Shrunk live weight basis

[b] Vitamin A requirements are 1000 IU per pound of diet.

[c] This table gives reasonable example of nutrient concentrations that should be suitable to formulate diets for specific management goals. It does not imply that diets with other nutrient concentrations when consumed in sufficient amounts would be inadequate to meet nutrient requirements.

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(Taken from Appendix Table 10 of ***Nutrient Requirements of Beef Cattle,*** Sixth revised edition, National Research Council, Subcommittee on Beef Cattle Nutrition, Committee on Animal Nutrition, Board on Agriculture, Washington, DC. 1984)

**Appendix Table 2 NR** Recommended Nutrient Content of Diets for Dairy Cattle

| Cow Wt. (lb) | Fat (%) | Wt. Gain (lb/d) | Lactating Cow Diets — Milk Yield (lb/d) | | | | | Early Lactation (wks 0-3) | Dry Pregnant Cows | Calf Milk Replacer | Calf Starter Mix | Growing Heifers and Bulls[a] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 3-6 mos | 6-12 mos | > 12 mos |
| 900 | 5.0 | 0.50 | 14 | 29 | 43 | 58 | 74 | | | | | | | |
| 1,100 | 4.5 | 0.60 | 18 | 36 | 55 | 73 | 91 | | | | | | | |
| 1,300 | 4.0 | 0.72 | 23 | 47 | 70 | 93 | 117 | | | | | | | |
| 1,500 | 3.5 | 0.82 | 26 | 52 | 78 | 104 | 130 | | | | | | | |
| 1,700 | 3.5 | 0.94 | 29 | 57 | 86 | 114 | 143 | | | | | | | |
| Energy | | | | | | | | | | | | | | |
| NEL, Mcal/lb | | | 0.65 | 0.69 | 0.73 | 0.78 | 0.78 | 0.76 | 0.57 | -- | -- | -- | -- | -- |
| NEM, Mcal/lb | | | -- | -- | -- | -- | -- | -- | -- | 1.09 | 0.86 | 0.77 | 0.72 | 0.63 |
| NEG, Mcal/lb | | | -- | -- | -- | -- | -- | -- | -- | 0.70 | 0.54 | 0.49 | 0.44 | 0.37 |
| ME, Mcal/lb | | | 1.07 | 1.16 | 1.25 | 1.31 | 1.31 | 1.27 | 0.93 | 1.71 | 1.41 | 1.18 | 1.12 | 1.03 |
| DE, Mcal/lb | | | 1.26 | 1.35 | 1.44 | 1.50 | 1.50 | 1.46 | 1.12 | 1.90 | 1.60 | 1.37 | 1.31 | 1.22 |
| TDN, % of DM | | | 63 | 67 | 71 | 75 | 75 | 73 | 56 | 95 | 80 | 69 | 66 | 61 |
| Protein equivalent | | | | | | | | | | | | | | |
| Crude protein, % | | | 12 | 15 | 16 | 17 | 18 | 19 | 12 | 22 | 18 | 16 | 12 | 12 |
| UIP, % | | | 4.5 | 5.4 | 5.7 | 6.0 | 6.3 | 7.2 | -- | -- | -- | 8.2 | 4.3 | 2.1 |
| DIP, % | | | 7.9 | 8.8 | 9.7 | 10.4 | 10.4 | 9.7 | -- | -- | -- | 4.6 | 6.4 | 7.2 |
| Fiber content (min.)[b] | | | | | | | | | | | | | | |
| Crude fiber, % | | | 17 | 17 | 17 | 15 | 15 | 17 | 22 | -- | -- | 13 | 15 | 15 |
| Acid detergent fiber,% | | | 21 | 21 | 21 | 19 | 19 | 21 | 27 | -- | -- | 16 | 19 | 19 |
| Neutral detergent fiber,% | | | 28 | 28 | 28 | 25 | 25 | 28 | 35 | -- | -- | 23 | 25 | 25 |
| Ether extract (min.), % | | | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 10 | 3 | 3 | 3 | 3 |
| Minerals | | | | | | | | | | | | | | |
| Calcium, % | | | 0.43 | 0.53 | 0.60 | 0.65 | 0.66 | 0.77 | 0.39[c] | 0.70 | 0.60 | 0.52 | 0.41 | 0.29 |
| Phosphorus, % | | | 0.28 | 0.34 | 0.38 | 0.42 | 0.41 | 0.49 | 0.24 | 0.60 | 0.40 | 0.31 | 0.30 | 0.23 |
| Magnesium, %[d] | | | 0.20 | 0.20 | 0.20 | 0.25 | 0.25 | 0.25 | 0.16 | 0.07 | 0.10 | 0.16 | 0.16 | 0.16 |
| Potassium, %[e] | | | 0.90 | 0.90 | 0.90 | 1.00 | 1.00 | 1.00 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| Sodium, % | | | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Chlorine, % | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Sulfur, % | | | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.25 | 0.16 | 0.29 | 0.20 | 0.16 | 0.16 | 0.16 |
| Iron, ppm | | | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 100 | 50 | 50 | 50 | 50 |
| Cobalt, ppm | | | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Copper, ppm[f] | | | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Manganese, ppm | | | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Zinc, ppm | | | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Iodine, ppm[g] | | | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Selenium, ppm | | | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Vitamins[h] | | | | | | | | | | | | | | |
| **A**, IU/lb | | | 1,450 | 1,450 | 1,450 | 1,450 | 1,450 | 1,800 | 1,800 | 1,700 | 1,000 | 1,000 | 1,000 | 1,000 |
| **D**, IU/lb | | | 450 | 450 | 450 | 450 | 450 | 450 | 540 | 270 | 140 | 140 | 140 | 140 |
| **E**, IU/lb | | | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 18 | 11 | 11 | 11 | 11 |

*Footnotes to Appendix Table 2 NR*

***Note:*** The values presented in this table are intended as guidelines for the use of professionals in diet formulation. Because of the many factors affecting such values, they are not intended and should not be used as a legal or regulatory base.

[a] The approximate weight for growing heifers and bulls at 3-6 mo is 331 lb; at 6-12 mo, it is 559 lb; and at more than 12 mo, it is 881 lb. The approximate average daily gain is 1.543 lb/day.

[b] It is recommended that 75% of the NDF in lactating cow diets be provided as forage. If this recommendation is not followed, a depression in milk fat may occur.

[c] The value for calcium assumes that the cow is in calcium balance at the beginning of the dry period. If the cow is not in balance, then the dietary calcium requirement should be increased by 25 to 33 percent.

[d] Under conditions conducive to grass tetany, magnesium should be increased to 0.25 or 0.30 percent.

[e] Under conditions of heat stress, potassium should be increased to 1.2 percent.

[f] The cow's copper requirement is influenced by molybdenum and sulfur in the diet.

[g] If the diet contains as much as 25 percent strongly goitrogenic feed on a dry basis, the iodine provided should be increased two times or more.

[h] The following minimum quantities of B-complex vitamins are suggested per unit of milk replacer: niacin, 2.6 ppm; pantothenic acid, 13 ppm; riboflavin, 6.5 ppm; pyridoxine, 6.5 ppm; folic acid, 0.5 ppm; biotin, 0.1 ppm; vitamin $B_{12}$, 0.07 ppm; thiamin, 6.5 ppm; and choline, 0.26 percent. It appears that adequate amounts of these vitamins are furnished when calves have functional rumens (usually at 6 weeks of age) by a combination of rumen synthesis and natural feedstuffs.

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(Taken from Appendix Table 5 **of *Nutrient Requirements of Dairy Cattle,*** Sixth revised edition, National Research Council, Subcommittee on Dairy Cattle Nutrition, Committee on Animal Nutrition, Board on Agriculture, Washington, DC. 1988)

**Appendix Table 3 NR** Daily Nutrient Requirements of Horses (880-lb mature weight)

| Animal | Weight (lb) | Daily Gain (lb) | DE (Mcal) | Crude Protein (lb) | Lysine (lb) | Calcium (lb) | Phosphorus (lb) | Vitamin A (1000 IU) |
|---|---|---|---|---|---|---|---|---|
| ***Mature horses*** | | | | | | | | |
| Maintenance | 882 | | 13.4 | 1.18 | 0.042 | 0.035 | 0.024 | 12 |
| Stallions (breeding season) | 882 | | 16.8 | 1.47 | 0.051 | 0.044 | 0.033 | 18 |
| Pregnant mares | | | | | | | | |
| 9 months | 882 | | 14.9 | 1.44 | 0.051 | 0.062 | 0.046 | 24 |
| 10 months | | | 15.1 | 1.47 | 0.051 | 0.064 | 0.048 | 24 |
| 11 months | | | 16.1 | 1.56 | 0.055 | 0.068 | 0.051 | 24 |
| Lactating mares | | | | | | | | |
| Foaling to 3 months | 882 | | 22.9 | 2.51 | 0.088 | 0.099 | 0.064 | 24 |
| 3 months to weaning | 882 | | 19.7 | 1.85 | 0.064 | 0.064 | 0.040 | 24 |
| Working horses | | | | | | | | |
| Light work[a] | 882 | | 16.8 | 1.47 | 0.051 | 0.044 | 0.033 | 18 |
| Moderate work[b] | 882 | | 20.1 | 1.77 | 0.062 | 0.055 | 0.037 | 18 |
| Intense work[c] | 882 | | 26.8 | 2.36 | 0.084 | 0.073 | 0.051 | 18 |
| ***Growing horses*** | | | | | | | | |
| Weanling, 4 months | 320 | 1.87 | 13.5 | 1.49 | 0.062 | 0.073 | 0.040 | 7 |
| Weanling, 6 months | | | | | | | | |
| Moderate growth | 397 | 1.21 | 12.9 | 1.41 | 0.060 | 0.055 | 0.031 | 8 |
| Rapid growth | 397 | 1.54 | 14.5 | 1.60 | 0.066 | 0.066 | 0.035 | 8 |
| Yearling, 12 months | | | | | | | | |
| Moderate growth | 584 | 0.88 | 15.6 | 1.54 | 0.066 | 0.051 | 0.029 | 12 |
| Rapid growth | 584 | 1.10 | 17.1 | 1.69 | 0.073 | 0.060 | 0.033 | 12 |
| Long yearling, 18 months | | | | | | | | |
| Not in training | 728 | 0.55 | 15.9 | 1.58 | 0.066 | 0.046 | 0.026 | 15 |
| In training | 728 | 0.55 | 21.6 | 2.13 | 0.090 | 0.064 | 0.035 | 15 |
| Two-year-old, 24 months | | | | | | | | |
| Not in training | 805 | 0.33 | 15.3 | 1.43 | 0.057 | 0.042 | 0.024 | 16 |
| In training | 805 | 0.33 | 21.5 | 2.01 | 0.081 | 0.060 | 0.033 | 16 |

**Note:** Mares should gain weight during late gestation to compensate for tissue deposition. However, nutrient requirements are based on maintenance body weight.

[a] Examples are horses used in Western and English pleasure, bridle path hack, equitation, etc.

[b] Examples are horses used in ranch work, roping, cutting, barrel racing, jumping, etc.

[c] Examples are horses used in race training, polo, etc.

(Taken from Table 5-1B of ***Nutrient Requirements of Horses,*** Fifth revised edition, National Research Council, Subcommittee on Horse Nutrition, Committee on Animal Nutrition, Board on Agriculture, Washington, DC. 1989)

**Appendix Table 4 NR** Daily Nutrient Requirements of Sheep

| Body Weight (lb) | Weight Change/ Day (lb) | Dry Matter[a] (lb) | Dry Matter[a] (% body weight) | Crude Protein (lb) | Energy ME (Mcal) | Ca (lb) | P (lb) | Vitamin A (IU) | Vitamin E (IU) |
|---|---|---|---|---|---|---|---|---|---|
| **EWES[b]** | | | | | | | | | |
| ***Maintenance*** | | | | | | | | | |
| 110 | 0.02 | 2.2 | 2.0 | 0.21 | 2.0 | 0.0044 | 0.0040 | 2,350 | 15 |
| 132 | 0.02 | 2.4 | 1.8 | 0.23 | 2.2 | 0.0051 | 0.0046 | 2,820 | 16 |
| 154 | 0.02 | 2.6 | 1.7 | 0.25 | 2.4 | 0.0055 | 0.0053 | 3,290 | 18 |
| 176 | 0.02 | 2.9 | 1.6 | 0.27 | 2.6 | 0.0060 | 0.0062 | 3,760 | 20 |
| 198 | 0.02 | 3.1 | 1.5 | 0.29 | 2.8 | 0.0064 | 0.0068 | 4,230 | 21 |
| ***Flushing - 2 weeks prebreeding and first 3 weeks of breeding*** | | | | | | | | | |
| 110 | 0.22 | 3.5 | 3.2 | 0.33 | 3.4 | 0.0117 | 0.0057 | 2,350 | 24 |
| 132 | 0.22 | 3.7 | 2.8 | 0.34 | 3.6 | 0.0121 | 0.0064 | 2,820 | 26 |
| 154 | 0.22 | 4.0 | 2.6 | 0.36 | 3.8 | 0.0126 | 0.0070 | 3,290 | 27 |
| 176 | 0.22 | 4.2 | 2.4 | 0.38 | 4.0 | 0.0130 | 0.0079 | 3,760 | 28 |
| 198 | 0.22 | 4.4 | 2.2 | 0.39 | 4.2 | 0.0134 | 0.0086 | 4,230 | 30 |
| ***Nonlactating - first 15 weeks gestation*** | | | | | | | | | |
| 110 | 0.07 | 2.6 | 2.4 | 0.25 | 2.4 | 0.0064 | 0.0046 | 2,350 | 18 |
| 132 | 0.07 | 2.9 | 2.2 | 0.27 | 2.6 | 0.0070 | 0.0055 | 2,820 | 20 |
| 154 | 0.07 | 3.1 | 2.0 | 0.29 | 2.8 | 0.0077 | 0.0064 | 3,290 | 21 |
| 176 | 0.07 | 3.3 | 1.9 | 0.31 | 3.0 | 0.0084 | 0.0073 | 3,760 | 22 |
| 198 | 0.07 | 3.5 | 1.8 | 0.33 | 3.2 | 0.0090 | 0.0079 | 4,230 | 24 |
| ***Last 4 weeks gestation (130-150% lambing rate expected)*** OR (in parentheses) ***Last 4-6 weeks lactation nursing singles*** | | | | | | | | | |
| 110 | 0.40 (0.10) | 3.5 | 3.2 | 0.38 | 3.4 | 0.0130 | 0.0106 | 4,250 | 24 |
| 132 | 0.40 (0.10) | 3.7 | 2.8 | 0.40 | 3.6 | 0.0132 | 0.0115 | 5,100 | 26 |
| 154 | 0.40 (0.10) | 4.0 | 2.6 | 0.42 | 3.8 | 0.0137 | 0.0123 | 5,950 | 27 |
| 176 | 0.40 (0.10) | 4.2 | 2.4 | 0.44 | 4.0 | 0.0139 | 0.0134 | 6,800 | 28 |
| 198 | 0.40 (0.10) | 4.4 | 2.2 | 0.47 | 4.2 | 0.0141 | 0.0143 | 7,650 | 30 |
| ***Last 4 weeks gestation (180-225% lambing rate expected)*** | | | | | | | | | |
| 110 | 0.50 | 3.7 | 3.4 | 0.43 | 4.0 | 0.0137 | 0.0075 | 4,250 | 26 |
| 132 | 0.50 | 4.0 | 3.0 | 0.45 | 4.2 | 0.0152 | 0.0088 | 5,100 | 27 |
| 154 | 0.50 | 4.2 | 2.7 | 0.47 | 4.4 | 0.0168 | 0.0099 | 5,950 | 28 |
| 176 | 0.50 | 4.4 | 2.5 | 0.49 | 4.7 | 0.0183 | 0.0112 | 6,800 | 30 |
| 198 | 0.50 | 4.6 | 2.3 | 0.51 | 5.0 | 0.0196 | 0.0126 | 7,650 | 32 |
| ***First 6-8 weeks lactation nursing singles*** OR (in parentheses) ***Last 4-6 weeks lactation nursing twins*** | | | | | | | | | |
| 110 | −0.06 (0.20) | 4.6 | 4.2 | 0.67 | 4.9 | 0.0196 | 0.0134 | 4,250 | 32 |
| 132 | −0.06 (0.20) | 5.1 | 3.8 | 0.70 | 5.4 | 0.0201 | 0.0145 | 5,100 | 34 |
| 154 | −0.06 (0.20) | 5.5 | 3.6 | 0.73 | 5.9 | 0.0205 | 0.0154 | 5,950 | 38 |
| 176 | −0.06 (0.20) | 5.7 | 3.2 | 0.76 | 6.1 | 0.0209 | 0.0163 | 6,800 | 39 |
| 198 | −0.06 (0.20) | 5.9 | 3.0 | 0.78 | 6.3 | 0.0212 | 0.0172 | 7,650 | 40 |
| ***First 6-8 weeks lactation nursing twins*** | | | | | | | | | |
| 110 | − 0.13 | 5.3 | 4.8 | 0.86 | 5.6 | 0.0231 | 0.0161 | 5,000 | 36 |
| 132 | − 0.13 | 5.7 | 4.3 | 0.89 | 6.1 | 0.0236 | 0.0170 | 6,000 | 39 |
| 154 | − 0.13 | 6.2 | 4.0 | 0.92 | 6.6 | 0.0242 | 0.0179 | 7,000 | 42 |
| 176 | − 0.13 | 6.6 | 3.8 | 0.96 | 7.0 | 0.0247 | 0.0190 | 8,000 | 45 |
| 198 | − 0.13 | 7.0 | 3.6 | 0.99 | 7.5 | 0.0251 | 0.0198 | 9,000 | 48 |
| **EWE LAMBS** | | | | | | | | | |
| ***Nonlactating - first 15 weeks gestation*** | | | | | | | | | |
| 88 | 0.35 | 3.1 | 3.5 | 0.34 | 3.0 | 0.0121 | 0.0066 | 1,880 | 21 |
| 110 | 0.30 | 3.3 | 3.0 | 0.35 | 3.2 | 0.0115 | 0.0068 | 2,350 | 22 |
| 132 | 0.30 | 3.5 | 2.7 | 0.35 | 3.4 | 0.0121 | 0.0075 | 2,820 | 24 |
| 154 | 0.28 | 3.7 | 2.4 | 0.36 | 3.6 | 0.0121 | 0.0081 | 3,290 | 26 |

*(continued)*

(Taken from Table 1 of ***Nutrient Requirements of Sheep,*** Sixth revised edition, National Research Council, Subcommittee on Sheep Nutrition, Committee on Animal Nutrition, Board on Agriculture, Washington, DC. 1985)

**Appendix Table 4 NR** *(page 2)*

| Body Weight (lb) | Weight Change/ Day (lb) | Dry Matter [a] (lb) | Dry Matter [a] (% body weight) | Crude Protein (lb) | Energy ME [b] (Mcal) | Ca (lb) | P (lb) | Vitamin A (IU) | Vitamin E (IU) |
|---|---|---|---|---|---|---|---|---|---|
| **EWE LAMBS** *(continued)* | | | | | | | | | |
| ***Last 4 weeks gestation (100-120% lambing rate expected)*** | | | | | | | | | |
| 88 | 0.40 | 3.3 | 3.8 | 0.41 | 3.4 | 0.0141 | 0.0068 | 3,400 | 22 |
| 110 | 0.35 | 3.5 | 3.2 | 0.42 | 3.6 | 0.0139 | 0.0075 | 4,250 | 24 |
| 132 | 0.35 | 3.7 | 2.8 | 0.42 | 3.9 | 0.0145 | 0.0084 | 5,100 | 26 |
| 154 | 0.33 | 4.0 | 2.6 | 0.43 | 4.1 | 0.0150 | 0.0093 | 5,950 | 27 |
| ***Last 4 weeks gestation (130-175% lambing rate expected)*** | | | | | | | | | |
| 88 | 0.50 | 3.3 | 3.8 | 0.44 | 3.6 | 0.0163 | 0.0077 | 3,400 | 22 |
| 110 | 0.50 | 3.5 | 3.2 | 0.45 | 3.8 | 0.0172 | 0.0086 | 4,250 | 24 |
| 132 | 0.50 | 3.7 | 2.8 | 0.46 | 4.0 | 0.0179 | 0.0095 | 5,100 | 26 |
| 154 | 0.47 | 4.0 | 2.6 | 0.46 | 4.1 | 0.0181 | 0.0104 | 5,950 | 27 |
| ***First 6-8 weeks lactation nursing singles (wean by 8 weeks)*** | | | | | | | | | |
| 88 | – 0.11 | 3.7 | 4.2 | 0.56 | 4.0 | 0.0132 | 0.0095 | 3,400 | 26 |
| 110 | – 0.11 | 4.6 | 4.2 | 0.62 | 5.0 | 0.0143 | 0.0104 | 4,250 | 32 |
| 132 | – 0.11 | 5.1 | 3.8 | 0.65 | 5.5 | 0.0150 | 0.0112 | 5,100 | 34 |
| 154 | – 0.11 | 5.5 | 3.6 | 0.68 | 6.0 | 0.0156 | 0.0123 | 5,450 | 38 |
| ***First 6-8 weeks lactation nursing twins (wean by 8 weeks)*** | | | | | | | | | |
| 88 | – 0.22 | 4.6 | 5.2 | 0.67 | 5.2 | 0.0185 | 0.0123 | 4,000 | 32 |
| 110 | – 0.22 | 5.1 | 4.6 | 0.71 | 5.7 | 0.0192 | 0.0132 | 5,000 | 34 |
| 132 | – 0.22 | 5.5 | 4.2 | 0.74 | 6.2 | 0.0198 | 0.0141 | 6,000 | 38 |
| 154 | – 0.22 | 6.0 | 3.9 | 0.77 | 6.6 | 0.0205 | 0.0152 | 7,000 | 40 |
| ***Replacement ewe lambs [c]*** | | | | | | | | | |
| 66 | 0.50 | 2.6 | 4.0 | 0.41 | 2.8 | 0.0141 | 0.0057 | 1,410 | 18 |
| 88 | 0.40 | 3.1 | 3.5 | 0.39 | 3.3 | 0.0130 | 0.0057 | 1,880 | 21 |
| 110 | 0.26 | 3.3 | 3.0 | 0.30 | 3.2 | 0.0106 | 0.0053 | 2,350 | 22 |
| 132 | 0.22 | 3.3 | 2.5 | 0.30 | 3.2 | 0.0099 | 0.0055 | 2,820 | 22 |
| 154 | 0.22 | 3.3 | 2.1 | 0.29 | 3.2 | 0.0101 | 0.0062 | 3,290 | 22 |
| ***Replacement ram lambs [c]*** | | | | | | | | | |
| 88 | 0.73 | 4.0 | 4.5 | 0.54 | 4.1 | 0.0172 | 0.0081 | 1,880 | 24 |
| 132 | 0.70 | 5.3 | 4.0 | 0.58 | 5.5 | 0.0185 | 0.0093 | 2,820 | 26 |
| 176 | 0.64 | 6.2 | 3.5 | 0.59 | 6.4 | 0.0187 | 0.0101 | 3,760 | 28 |
| 220 | 0.55 | 6.6 | 3.0 | 0.58 | 6.9 | 0.0181 | 0.0106 | 4,700 | 30 |
| ***Lambs finishing - 4 -7 months old [d]*** | | | | | | | | | |
| 66 | 0.65 | 2.9 | 4.3 | 0.42 | 3.4 | 0.0145 | 0.0070 | 1,410 | 20 |
| 88 | 0.60 | 3.5 | 4.0 | 0.41 | 4.4 | 0.0145 | 0.0073 | 1,880 | 24 |
| 110 | 0.45 | 3.5 | 3.2 | 0.35 | 4.4 | 0.0123 | 0.0066 | 2,350 | 24 |
| ***Early weaned lambs - moderate growth potential [d]*** | | | | | | | | | |
| 22 | 0.44 | 1.1 | 5.0 | 0.38 | 1.4 | 0.0088 | 0.0042 | 470 | 10 |
| 44 | 0.55 | 2.2 | 5.0 | 0.37 | 2.9 | 0.0119 | 0.0055 | 940 | 20 |
| 66 | 0.66 | 2.9 | 4.3 | 0.42 | 3.6 | 0.0148 | 0.0070 | 1,410 | 20 |
| 88 | 0.76 | 3.3 | 3.8 | 0.44 | 4.2 | 0.0170 | 0.0086 | 1,880 | 22 |
| 110 | 0.66 | 3.3 | 3.0 | 0.40 | 4.2 | 0.0154 | 0.0084 | 2,350 | 22 |
| ***Early weaned lambs - rapid growth potential [d]*** | | | | | | | | | |
| 22 | 0.55 | 1.3 | 6.0 | 0.35 | 1.7 | 0.0108 | 0.0049 | 470 | 12 |
| 44 | 0.66 | 2.6 | 6.0 | 0.45 | 3.3 | 0.0143 | 0.0064 | 940 | 24 |
| 66 | 0.72 | 3.1 | 4.7 | 0.48 | 4.0 | 0.0159 | 0.0075 | 1,410 | 21 |
| 88 | 0.88 | 3.3 | 3.8 | 0.51 | 4.1 | 0.0190 | 0.0095 | 1,880 | 22 |
| 110 | 0.94 | 3.7 | 3.4 | 0.53 | 4.7 | 0.0207 | 0.0106 | 2,350 | 25 |
| 132 | 0.77 | 3.7 | 2.8 | 0.53 | 4.7 | 0.0181 | 0.0099 | 2,820 | 25 |

[a] To convert dry matter to an as-fed basis, divide dry matter values by the percentage of dry matter in the particular feed.

[b] Values are applicable for ewes in moderate condition. Fat ewes should be fed according to the next lower weight category and thin ewes at the next higher weight category. Once desired or moderate weight condition is attained, use that weight category through all production stages.

[c] Lambs intended for breeding; thus, maximum weight gains and finish are of secondary importance.

[d] Maximum weight gains expected.

**Appendix Table 5 NR** Nutrient Requirements of Swine Allowed Feed Ad Libitum (90% dry matter)

| Intake and Performance Levels | Swine Liveweight (lb) 2–10 | 11–21 | 22–43 | 44–109 | 110–240 |
|---|---|---|---|---|---|
| Expected weight gain (lb/day) | 0.44 | 0.55 | 1.0 | 1.54 | 1.8 |
| Expected feed intake (lb/day) | 0.55 | 1.01 | 2.1 | 4.2 | 6.9 |
| Expected efficiency (gain/feed) | 0.80 | 0.543 | 0.474 | 0.368 | 0.264 |
| Expected efficiency (feed/gain) | 1.25 | 1.84 | 2.11 | 2.71 | 3.79 |
| Metabolizable energy intake (Mcal/day) | 805 | 1,490 | 3,090 | 6,200 | 10,185 |
| Energy concentration (Mcal ME/lb diet) | 1.46 | 1.47 | 1.474 | 1.478 | 1.485 |
| Protein | 24% | 20% | 18% | 15% | 13% |
| NUTRIENT | Requirement (% in diet)* | | | | |
| Indispensable amino acids (%) | | | | | |
| Arginine | 0.60 | 0.50 | 0.40 | 0.25 | 0.10 |
| Histidine | 0.36 | 0.31 | 0.25 | 0.22 | 0.18 |
| Isoleucine | 0.76 | 0.65 | 0.53 | 0.46 | 0.38 |
| Leucine | 1.00 | 0.85 | 0.70 | 0.60 | 0.50 |
| Lysine | 1.40 | 1.15 | 0.95 | 0.75 | 0.60 |
| Methionine + cystine | 0.68 | 0.58 | 0.48 | 0.41 | 0.34 |
| Phenylalanine + tyrosine | 1.10 | 0.94 | 0.77 | 0.66 | 0.55 |
| Threonine | 0.80 | 0.68 | 0.56 | 0.48 | 0.40 |
| Tryptophan | 0.20 | 0.17 | 0.14 | 0.12 | 0.10 |
| Valine | 0.80 | 0.68 | 0.56 | 0.48 | 0.40 |
| Linoleic acid (%) | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Mineral elements | | | | | |
| Calcium (%) | 0.90 | 0.80 | 0.70 | 0.60 | 0.50 |
| Phosphorus, total (%) | 0.70 | 0.65 | 0.60 | 0.50 | 0.40 |
| Phosphorus, available (%) | 0.55 | 0.40 | 0.32 | 0.23 | 0.15 |
| Sodium (%) | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Chlorine (%) | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Magnesium (%) | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Potassium (%) | 0.30 | 0.28 | 0.26 | 0.23 | 0.17 |
| Copper (mg or ppm) | 6.0 | 6.0 | 5.0 | 4.0 | 3.0 |
| Iodine (mg or ppm) | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| Iron (mg or ppm) | 100 | 100 | 80 | 60 | 40 |
| Manganese (mg or ppm) | 4.0 | 4.0 | 3.0 | 2.0 | 2.0 |
| Selenium (mg or ppm) | 0.30 | 0.30 | 0.25 | 0.15 | 0.10 |
| Zinc (mg or ppm) | 100 | 100 | 80 | 60 | 50 |
| Vitamins | | | | | |
| Vitamin A (IU) | 2,200 | 2,200 | 1,750 | 1,300 | 1,300 |
| Vitamin D (IU) | 220 | 220 | 200 | 150 | 150 |
| Vitamin E (IU) | 16 | 16 | 11 | 11 | 11 |
| Vitamin K (menadione) (mg or ppm) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Biotin (mg or ppm) | 0.08 | 0.05 | 0.05 | 0.05 | 0.05 |
| Choline (g) | 0.6 | 0.5 | 0.4 | 0.3 | 0.3 |
| Folacin (mg or ppm) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Niacin, available (mg or ppm) | 20.0 | 15.0 | 12.5 | 10.0 | 7.0 |
| Pantothenic acid (mg or ppm) | 12.0 | 10.0 | 9.0 | 8.0 | 7.0 |
| Riboflavin (mg or ppm) | 4.0 | 3.5 | 3.0 | 2.5 | 2.0 |
| Thiamin (mg or ppm) | 1.5 | 1.0 | 1.0 | 1.0 | 1.0 |
| Vitamin $B_6$ (mg or ppm) | 2.0 | 1.5 | 1.5 | 1.0 | 1.0 |
| Vitamin $B_{12}$ (µg or ppm) | 20.0 | 17.5 | 15.0 | 10.0 | 5.0 |

***Note:*** Knowledge of nutritional constraints and limitations is important for the proper use of this table.

* These requirements are based upon the following types of pigs and diets: 2—10-lb pigs, a diet that includes 25 to 75% milk products; 11—21-lb pigs, a corn-soybean meal diet that includes 5 to 25% milk products; 22—240-lb pigs, a corn-soybean meal diet. In the corn-soybean meal diets, the corn contains 8.5% protein; the soybean meal contains 44% protein.

(Taken from Table 5-1 of ***Nutrient Requirements of Swine,*** Ninth revised edition, National Research Council, Subcommittee on Swine Nutrition, Committee on Animal Nutrition, Board on Agriculture, Washington, DC. 1988)

**Appendix Table 6** Weight-Unit Conversion Factors

| *If the measure is given in this unit* | *Multiply (X) by this conversion factor* | *To obtain this unit* |
|---|---|---|
| lb | 0.453592 | kg |
| kg | 2.204624 | lb |
| lb | 453.592 | g |
| g | 0.0022046 | lb |
| lb | 453,592.0 | mg |
| mg | 0.0000022046 | lb |
| oz | 0.02835 | kg |
| kg | 35.2734 | oz |
| oz | 28.35 | g |
| g | 0.03527 | oz |
| ton (short, 2000 lb) | 907.185 | kg |
| kg | 0.0011 | ton (short, 2000 lb) |
| tonne | 1000 | kg |
| kg | 0.001 | tonne |
| kg | 1,000,000 | mg |
| mg | 0.000001 | kg |
| kg | 1000 | g |
| g | 0.001 | kg |
| g | 1000 | mg |
| mg | 0.001 | g |
| g | 1,000,000 | µg |
| µg | 0.000001 | g |
| mg | 1000 | g |
| µg | 0.001 | mg |
| mg/kg | 0.453592 | mg/lb |
| mg/lb | 2.2046 | mg/kg |
| mg/g | 453.592 | mg/lb |
| mg/lb | 0.0022046 | mg/g |
| g/kg | 0.453592 | g/lb |
| g/lb | 2.2046 | g/kg |
| kg/kg | 0.453592 | kg/lb |
| kg/lb | 2.2046 | kg/kg |
| kcal/kg | 0.453592 | kcal/lb |
| kcal/lb | 2.2046 | kcal/kg |
| Mcal/kg | 0.453592 | Mcal/lb |
| Mcal/lb | 2.2046 | Mcal/kg |
| IU/kg | 0.453592 | IU/lb |
| IU/lb | 2.2046 | IU/kg |
| ICU/kg | 0.453592 | ICU/lb |
| ICU/lb | 2.2046 | ICU/kg |
| µg/kg | 0.453592 | µg/lb |
| µg/lb | 2.2046 | µg/kg |
| g/Mcal | 0.0022046 | lb/Mcal |
| lb/Mcal | 453.592 | g/Mcal |
| Mcal | 1000 | kcal |
| kcal | 0.001 | Mcal |
| ppm | 1.0 | µg/g |
| ppm | 1.0 | mg/g |
| ppm | 0.453592 | mg/lb |
| ppm | 0.0001 | % |
| mg/kg | 0.0001 | % |
| mg/g | 0.1 | % |
| g/kg | 0.1 | % |

## GLOSSARY

| | |
|---|---|
| **abomasum** | the fourth compartment of a ruminant's stomach, similar to the stomach of non-ruminants; contains digestive glands |
| **abortion** | delivery of a fetus before it is fully developed and ready for birth |
| **absorption** | the process of taking nutrients into the blood stream through cell walls of the digestive organs |
| **acid** | a sour substance with hydrogen-containing molecules that on the pH scale of measurement is *lower* than 7.0 (neutral) |
| **active transport** | movement of nutrients from the digestive tract into the blood stream, requiring expending energy. |
| **ad libitum** | having free choice or access to feed or water |
| **additive** | ingredient(s) added to the basic feed mix usually in small quantities to fill a specific need. |
| **air dry** | dry so that no further moisture is given up upon exposure to air (approximately 90% dry matter) |
| **aleurone** | the outer layer of cells of the endosperm of a seed; found in wheat middlings |
| **alimentary canal** | another name for the gastrointestinal tract- the passage in the body through which food passes from mouth through stomach and intestines to anus |
| **alkaline** | having marked basic properties; a substance that on the pH scale of measurement is *higher* than 7.0 (neutral) |
| **ambient** | surrounding on all sides |
| **amino acid** | the 'building block' of protein; the form in which protein is absorbed into the blood-stream |
| **anemia** | a deficiency in the blood of red blood cells or hemoglobin |
| **annuals** | plants that complete their life cycle from seed to maturity in one year |
| **antibiotic** | class of drug that is used to prevent or control disease produced by microorganisms in animals |
| **antibody** | a substance produced in the body in response to the presence of a foreign body or substance |
| **anus** | opening at the end of the digestive tract |
| **as-fed** | moisture content of feed when fed to livestock 'as is' |
| **ash** | solid residue which remains when feedstuffs are burned or oxidized chemically |
| **auger** | a piece of equipment used for moving bulk feed; composed of a tube and screw mechanism |
| **avoirdupois weight** | the system of weight measurement based on one pound = 16 ounces |
| **bioconverting** | the process of living organisms changing organic matter into energy sources such as methane |

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| | |
|---|---|
| **bloat** | digestive disturbance of ruminants marked by swelling of the abdomen with gas |
| **body composition** | total of all the substances that make up the body of an animal |
| **bomb calorimeter** | device used to measure gross energy content of a feedstuff by burning a sample |
| **bulk** | indigestible fibers in feed |
| **by-product** | secondary products produced in an industrial process in addition to the main product |
| **calorie** | a measure of energy: the amount of heat required to raise the temperature of one gram of water one degree Celsius |
| **carbohydrate** | a major class of animal nutrients - sugars, starches, and celluloses |
| **carcass** | dressed body of a meat animal following slaughter |
| **carnivore** | flesh-eating mammal |
| **carotene** | pigment found in fatty tissues of plant-eating animals that is convertible to Vitamin A |
| **catalyst** | a substance, such as an enzyme, that can speed up the rate of a chemical reaction without being destroyed or inactivated in the process |
| **cecum** | the "blind gut" or pouch from which the large intestine begins |
| **cell membrane** | plasma membrane, the outer wall of an animal cell |
| **cellulose** | glucose compound that makes up most of plant cell walls |
| **coagulation** | becoming thickened, clotted |
| **coefficient** | a number that indicates the kind and amount of change in a substance under a given condition |
| **colon** | the large intestine between the cecum and rectum |
| **colostrum** | milk that is secreted for a few days by a female animal that has just given birth; it is high in protein and antibodies. |
| **commodities** | products of agriculture; economic goods such as corn grain, eggs, wool |
| **compensating** | equivalent |
| **compound** | a chemical substance made up of two or more elements; example- water, which is composed of hydrogen and oxygen |
| **concentrate** | a feedstuff rich in digestible nutrients |
| **conformation** | the shape or proportionate dimensions of an animal |
| **consumption** | taking into the body; eating or drinking |
| **creep feeding** | special diet fed only to young animals in feeders to which adults do not have access |
| **crimping** | process of rolling feed using corrugated rollers |
| **deficiency** | shortage of nutrients necessary to maintain good health and efficient production |
| **dehydration** | abnormal loss of water from the body without replacement |

| | |
|---|---|
| **die** | perforated block through which feed is forced to form pellets |
| **diet** | the kind and amount of food chosen for an animal for a particular purpose |
| **diet analysis** | lab testing and checking of all the components that make up a feed |
| **diffusion** | movement in body tissues of dissolved substances from a region of higher concentration to one of lower concentration |
| **digestion** | the process of making food absorbable in the body by breaking it down into simpler compounds |
| **dry matter (DM)** | the material which remains when all moisture has been removed from a feed |
| **duodenum** | the first section of the small intestine |
| **element** | one of over 100 known chemical substances that cannot be divided into smaller substances by chemical means |
| **emulsify** | to convert a fat into a substance in suspension in a liquid; also, a process of blending oils or fats with water to form an evenly distributed product |
| **energy** | the capacity for doing work |
| **ensilage** | the process of preserving high-moisture feeds through storage and fermentation in the absence of air |
| **enterotoxemia** | a disease caused by build-up of toxic substances produced by *Clostridium* bacteria in the digestive tract |
| **enzyme** | a complex protein produced by living cells that can assist chemical reactions in the body |
| **epithelium** | body tissue that lines a tube or cavity and produces secretions and excretions |
| **equivalent values** | substitute for a certain feed material that is roughly the same in nutritional value |
| **esophagus** | the tube through which food and water pass from the mouth to the stomach |
| **excerpt** | part of the complete table copied and used in this manual |
| **extract** | process of removing fat or oil from feedstuffs using organic solvents |
| **extrusion** | forcing wet feed under pressure through small holes, usually to form feed pellets |
| **farrowing** | giving birth to young pigs |
| **fatty acid** | major component of fat |
| **feces** | body waste discharged through the anus |
| **feed bunk** | a feeder used with large livestock |
| **feedstuff** | any particular feed item that is used to feed livestock |
| **fermentation** | breakdown of energy-rich compounds by bacterial action |
| **fetus** (fetal) | an unborn animal after it has developed the basic structure of its kind |
| **fistula** | an artificial passage from the body surface of an animal into a hollow organ, permitting material to pass through and be removed for analysis |

| | |
|---|---|
| **flushing** | special high-energy diet for a female animal provided 2 to 3 weeks before breeding |
| **foaling** | birth of a young horse (foal) |
| **fodder** | coarse feed for animals, such as cornstalks, hay, and straw |
| **forage** | vegetative material in fresh, dried, or ensiled state which is fed to livestock |
| **formulate** | plan an animal's diet so that nutrients provided are in balance with nutrients required |
| **free choice** | making food available to an animal to eat at will |
| **freshening** | beginning of lactation (milk production) in a cow that has given birth to a calf |
| **gastrointestinal** | major portion of the digestive tract, involving both the stomach and the intestine |
| **genetic** | the particular hereditary make-up of an animal |
| **gestation** | pregnancy; the period of development of a fetus in the uterus until birth |
| **gilt** | young female pig |
| **glucose** | simple sugar in the form easily utilized by animals |
| **gluten** | an elastic protein substance in wheat flour that makes dough stick together |
| **glycogen** | the main form of complex sugar in which carbohydrate is stored in animal tissue |
| **green chop** | forages which are harvested and fed directly to animals |
| **hammer mill** | a grinder or crusher which processes feed materials into a more convenient form for handling and digestion |
| **haylage** | stored forage made of grass silage wilted to 35-50% moisture |
| **hemoglobin** | the iron-containing protein in red blood cells that carries oxygen |
| **hemorrhage** | heavy bleeding from a broken blood vessel |
| **herbivore** | an animal that eats plants |
| **hormone** | a substance secreted in one part of the body that circulates in fluids and produces a specific effect on cell activity in another part of the body |
| **implant** | insert into the body, under the skin, as with hormones |
| **inert** | lacking in usual chemical or biological action - the so-called 'trash' in grain |
| **infestation** | spreading of a particular troublesome pest or organism |
| **inorganic** | mineral; a substance that does not contain carbon and has no plant or animal origin |
| **jaundice** | abnormal condition in which the skin turns yellowish |
| **ketosis** | an abnormal increase of ketones in an animal's body; commonly occurs in late gestation or early lactation |
| **lactation** | milk production and secretion by the female |

| | |
|---|---|
| **legumes** | a plant family with true pods containing seeds and nitrogen-fixing bacteria living in their roots; examples are peas, beans, clovers |
| **life cycle** | the series of stages in form and activity through which an organism passes in its development, back to the primary stage |
| **limestone** | rock that is chiefly calcium carbonate, a good source of calcium, yielding lime when burned |
| **lipid** | one of a large variety of organic fat or fatlike compounds; includes fats, waxes, steroids, etc. |
| **lubricate** | make smooth or slippery |
| **lymph** | clear fluid in the body that bathes the tissues, is carried by ducts, and contains white blood cells |
| **macro-element** | major element considered essential to good nutrition; measurable in grams, etc. |
| **maintenance diet** | a diet that just meets an animal's basic needs with nothing extra for production purposes |
| **mastitis** | inflammation of the udder caused by infection |
| **metabolism** | the chemical changes in living cells by which energy is provided for vital processes and new material is assimilated |
| **metric system** | the decimal system of weights and measures based on the meter and the kilogram |
| **micro-element** | trace element, measurable in milligrams, ppm, etc; necessary part of the diet |
| **microorganisms** | very tiny organisms visible only with a microscope, e.g. bacteria, viruses, protozoa |
| **middlings** | a milling by-product of wheat processing used in animal feeds |
| **milk replacer** | specially formulated substance fed to newborn animals in place of milk |
| **nodule** | a swelling on the root of a legume that contains beneficial bacteria |
| **nonruminant** | an animal that does not chew its cud and has a single stomach compartment |
| **noxious** | physically harmful or destructive |
| **nutrient** | substance or ingredient that is part of the diet of an animal; it helps maintain good health and promote growth |
| **omasum** | third chamber of the ruminant stomach, the function of which is little known |
| **omnivore** | animal that feeds on both animal and vegetable substances |
| **'open' female** | a female that is not pregnant |
| **organic** | matter containing carbon compounds, originally derived from living things |
| **osmosis** | movement of water through a semipermeable membrane into a solution of higher solute concentration |
| **osteomalacia** | a disease like rickets characterized by softening of the bones |
| **oxidation** | combination with oxygen; the animal combines carbon from its diet with inhaled oxygen to produce carbon dioxide, energy, water, and heat. |

| | |
|---|---|
| **palatable** (palatability) | agreeable to the palate or taste |
| **papillae** | small projections of a body organ that increase the absorption surface of that organ |
| **perennials** | plants that continue to live for more than two years |
| **peristalsis** | waves of involuntary muscle contractions in the wall of the intestine that force the contents to move forward. |
| **pH** | measurement of the degree of acidity or alkalinity according to hydrogen ion concentration, 7 being neutral. |
| **postpartum** | the time immediately following birth |
| **precursor** | a compound that can be used by the body to form another compound, e.g. carotene is a precursor of Vitamin A |
| **premix** | a uniform mixture of one or more micro-ingredients with a carrier; used when incorporating micro-ingredients into a larger mixture |
| **prepartum** | the time just before birth |
| **productivity** | the rate of production of particular animal products |
| **protein** | a nutrient made up of amino acids; essential for maintenance, growth, and reproduction |
| **putrefaction** | anaerobic decomposition of proteins by bacteria and fungi; the 'end-product' is foul-smelling and incompletely oxidized |
| **regurgitate** | to throw back up out of the stomach into the mouth, as by ruminants |
| **resin** | natural organic substance formed in plant secretions, soluble in ether |
| **respiration** | the processes in the body involved in the intake of oxygen (needed for metabolism) and the removal of carbon dioxide as a waste product |
| **reticulum** | second compartment of the ruminant stomach with folds of tissue; acts as a pump |
| **rickets** | a disease of calcium and phosphorus deficiency linked with Vitamin D deficiency that results in soft and deformed bones |
| **roughage** | coarse bulky food that is high in fiber and low in nutrients; also, any feed with over 18% fiber content |
| **rumen** | large first compartment of the ruminant stomach in which cellulose is broken down by microorganisms |
| **ruminant** | an animal that chews its cud and has a complex chambered stomach |
| **ruminate** | to chew again what has been chewed slightly, swallowed, and then regurgitated |
| **scours** | diarrhea |
| **self-fed** | feeding system that provides animals continuous free access to some or all the parts of their diet |
| **soluble** | capable of being emulsified or dissolved |
| **spoilage** | loss of good quality material by decay |

| | |
|---|---|
| **stillborn** | dead at birth |
| **stover** | mature cured stalks of grain with ears removed, used as feed for livestock |
| **succulent** | having fleshy tissues; juicy |
| **supplement** | feed used with another feed to improve the total nutritive balance or performance |
| **synthesis** | production of a new substance by the union of two or more chemical elements or groups |
| **synthetic** | product produced artificially by chemical or biochemical means |
| **tankage** | dried animal residues from the slaughter process, used as feedstuffs |
| **tetany** | condition of muscle spasms, etc. caused by mineral imbalance |
| **thrifty** | growing vigorously |
| **thyroxine** | hormone and amino acid from the thyroid gland, used to treat thyroid disorders |
| **toxic** | poisonous |
| **trace minerals** | mineral nutrients required by animals in micro or small amounts only |
| **transponder** | radar (or radio) set that receives messages and responds to identify objects |
| **unthrifty** | not in the best physical condition |
| **urea** | a nitrogenous compound found in animal urine and used in animal diets |
| **villus**, villi | a tiny finger-like projection of the mucous membrane of the small intestine that helps in absorption of nutrients |
| **volatile fatty acids** | important components of lipids, most commonly, acetic, propionic, and butyric acids |
| **wax** | a substance of plant or animal origin like fats, but harder, less greasy, and more brittle |
| **weanling** | a newly weaned animal; one that has recently been removed from its source of milk |
| **whey** | watery part of milk separated from the solids during cheese making; material is rich in lactose, minerals, and vitamins |